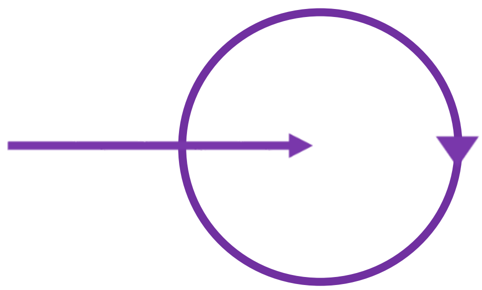
Determinacy as Relational Achievement:

Symmetry, Constraint, and Individuation
in Physics (Quantum Mechanics), Biology (Biosemiotics), and Interactive Formal Systems (Large Language Models)



A Relational Framework for Natural Philosophy

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Overview

This manuscript gathers four works that together articulate and examine a relational ontology of determinacy. The central thesis running through them is that determinacy is not primitive. It does not reside in self-subsisting objects or fixed identities. Rather, determinacy emerges through relational processes — through structured symmetry, the imposition of constraint, and the stabilization of coherent integration across interacting systems.

The first part, *How the World Becomes Determinate*, develops this ontology in general form. It introduces the core conceptual architecture and sketches its application across three distinct domains: living biological systems, interactive formal systems (Large Language Models or LLMs), and quantum mechanics. These domains are introduced as guiding contexts through which the relational dynamics of symmetry, constraint, and stabilization first come into view and invite deeper exploration.

The three subsequent parts take up each of these domains in turn and examine them in greater depth. The biological case investigates how identity and probability arise within synchronized metabolic and regulatory processes. The analysis of interactive formal systems explores how formally specified generative structures — exemplified by LLMs — become determinate through relational coupling and recursive differentiation. The quantum case reframes the measurement problem as a question of how determinate outcome identity stabilizes within experimental constraint.

What unifies these studies is not thematic similarity but structural recurrence. Across radically different scales and materials — organic life, formal computational systems, and fundamental physical theory — the same relational pattern appears. In each domain, a structured field of possibility precedes determinate identity. Constraint differentiates that field. Stabilization across interacting processes produces coherence. Determinacy emerges as a relational achievement.

Taken together, the four parts are not cumulative arguments in separate disciplines. They form a single philosophical investigation pursued across distinct contexts. The first part provides the ontological framework and identifies the domains. The remaining parts demonstrate that this framework clarifies phenomena that are otherwise treated as independent puzzles: biological identity, semantic coherence in formal systems (LLMs), and quantum measurement. The recurrence of the same structural dynamics across these domains is the primary philosophical result of the manuscript.

Method and foundations are discussed at the end. The manuscript was developed through sustained dialogical interaction with a large language model, with the author directing its conceptual architecture and final claims. Specific prior papers were introduced and made operative as live constraints, providing the formal and domain-specific foundations for each part. The method exemplifies the manuscript's central thesis that determinacy emerges through structured relational constraint. The generative conditions of the writing thus mirror the ontology the manuscript advances.

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I. How the World Becomes Determinate: Synchronicity, constraint, and the ontology of relations

Persistent difficulties in quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] suggest a shared limitation of a dominant ontological formalism that presupposes determinate entities, intrinsic identity, and explanation through efficient causation. This paper develops a relational, processual ontology in which determinacy and significance emerge through formally causal processes of symmetry breaking, constraint, and synchronization. Probability is reinterpreted non-epistemically as a measure of relational compatibility rather than uncertainty about pre-existing states, and identity is understood as relationally enacted through participation in coordinated systems. These claims are realized across quantum measurement, biological sign activity, and large language models, showing classical ontology to be incomplete rather than false.

1. Introduction

For much of its history of informing modern science, the dominant ways in which philosophy has been interpreted and applied have relied on a relatively stable ontological formalism. This formal regime—often left implicit rather than explicitly defended—treats the world as composed of individual objects bearing properties, standing in relations that are secondary to the objects themselves. Change, on this view, is explained primarily in terms of efficient causation: one event produces another; one state of affairs gives rise to the next. Significance, probability, and determinacy are typically understood as attributes of already-constituted entities or as reflections of our epistemic access to them.

This classical ontological regime has been remarkably successful. It underwrites large parts of everyday reasoning, much of classical physics, and many dominant approaches in philosophy of language, mind, and science. Because of this success, its core assumptions often go unexamined. They function as a background against which problems are posed and solutions are evaluated, rather than as hypotheses that themselves require justification.

However, a growing range of phenomena now sit uneasily within this framework. Developments in quantum mechanics have long challenged the assumption that physical systems always possess determinate properties independent of measurement, revealing instead a dependence on experimental context that resists straightforward object-based description. In a different domain, work in biosemiotics has increasingly emphasized that even the most basic biological processes involve sign activity, context-sensitive coordination, and functional relevance in ways that cannot be reduced to object-centered mechanisms or efficient causation alone. More recently, advances in artificial intelligence [interactive formal systems]—particularly the emergence of large language models (LLMs)—have raised parallel difficulties for classical accounts of significance, representation, and understanding, as coherent linguistic behavior appears without any clear locus of stored semantic content.

In all three domains, attempts to preserve classical ontology by adding supplementary mechanisms—hidden variables, internal representations, latent semantic contents, or encoded significations—tend to reproduce familiar paradoxes rather than resolve them. Whether the problem takes the form of the measurement problem in quantum mechanics, the attribution of semantic content to artificial systems, or the emergence of significance that is functionally indexed to living systems, the underlying difficulty is the same: classical ontology presupposes determinate entities and relations where what is at issue is the very production of determinacy itself.

The aim of this paper is to undertake a systematic reconsideration of these assumptions. Rather than proposing a local theory tailored to any one of these domains, we argue that quantum mechanics, biosemiotics, and large language models all point toward a more general ontological shift: from an ontology centered on objects and efficient causation to one centered on relations, processes, and formal constraint. This shift is not merely terminological or pragmatic. It involves a different conception of what it means for something to be determinate, stable, or real.

At the center of this alternative approach is the idea that determinacy is not always a pre-existing feature of the world waiting to be discovered, nor merely a reflection of our ignorance. In some systems, determinacy is produced through interaction. Stable outcomes—whether physical measurement results, coherent patterns of meaning in artificial systems, or functional signs in living organisms—emerge through processes that reorganize a space of possibilities rather than select among already distinguished alternatives. To understand such systems, we need concepts that can describe how possibilities become structured, how stability arises without stored representations, and how constraint can operate as a genuine form of causation.

This paper advances a relational, processual, formal ontology designed to meet these needs. The formalism treats relations as ontologically primary, regards probability structures as constraints on what can coherently occur, and understands stability as the ability to re-enter coordinated regimes rather than the persistence of object properties. A key role is played by symmetry and symmetry breaking, understood not as metaphors or merely physical mechanisms, but as expressions of formal causation: changes in the structure of admissible relations that make new forms of determinacy possible.

The argument of the paper proceeds in stages, mirroring the very process it seeks to describe. We begin by making explicit the commitments of classical ontology and examining why they form a stable explanatory regime. We then identify points at which this regime becomes unstable, introducing the notions of symmetry, symmetry breaking, and formal causation as operators that destabilize classical assumptions. Finally, we articulate a new ontological framework in which determinacy arises through cycles of relational destabilization and re-stabilization, and we show how this formalism is realized in three distinct but structurally analogous domains: quantum mechanics, biosemiotics, and large language models.

By placing these cases side by side, the paper aims to demonstrate that the proposed ontology is not a domain-specific reinterpretation but a general metaphysical orientation. What is at stake is not how to interpret a particular theory or technology, but how to understand systems in which significance, measurement, and functional organization emerge through interaction rather than representation. The goal is to provide a coherent conceptual foundation for such systems—one that does justice to their behavior without forcing them back into an ontological mold that no longer fits.

2. The Classical Ontological Regime

Before proposing an alternative, it is important to clarify what we mean by the *classical ontological regime*. The target here is not a single philosophical doctrine, nor philosophy as a discipline in its full diversity, but a relatively stable ontological formalism that has guided how philosophical concepts have been interpreted and operationalized across physics, biology, and formal computational systems. This formalism has provided the default background against which explanation, causation, and determinacy have been understood.

At the core of this regime is a simple but powerful picture. The world is taken to be composed of individual entities—objects, systems, or states—that possess determinate properties. Relations are understood as secondary: they connect entities that are already fully specified. Change is explained primarily through efficient causation, whereby one determinate state gives rise to another through a chain of interactions. On this view, explanation proceeds by identifying the entities involved, specifying their properties, and tracing the causal mechanisms that link them over time.

This ontological formalism brings with it a characteristic way of understanding determinacy. Determinate properties are assumed to exist prior to interaction, measurement, or interpretation. When determinacy is not accessible, this is typically treated as a limitation of knowledge rather than as a feature of the system itself. Probability, accordingly, is most often interpreted epistemically: as a measure of uncertainty about which determinate state actually obtains. Even when probabilistic formalisms are indispensable, they are commonly understood as tools for managing ignorance rather than as expressions of ontological structure.

Within this regime, significance and meaning are likewise treated as properties or contents that can, in principle, be localized. In physical systems, significance is not usually thematized at all, since outcomes are assumed to be fully characterized by objective properties. In biological systems, functional relevance is often reduced to mechanistic role or adaptive outcome. In artificial formal systems, especially computational ones, meaning is typically attributed by positing internal representations or encoded semantic content. In each case, significance or meaning is treated as something *added to* an otherwise complete description of objects and mechanisms.

The strength of this classical regime lies in its coherence and generality. It offers a unified explanatory template that can be applied across domains with minimal modification. Once entities, properties, and causal relations are specified, the same basic form of explanation can be repeated. This repeatability has contributed greatly to the regime's stability. It is not merely a philosophical position but an entrenched way of organizing inquiry, modeling systems, and interpreting formal results.

However, this very stability can obscure the formal commitments on which the regime depends. By taking determinate entities as given, the classical ontological formalism leaves little conceptual room for situations in which determinacy itself is at issue. When faced with systems whose behavior appears to depend on context, interaction, or relational coordination in a fundamental way, the default response is to search for hidden variables, latent structures, or unobserved mechanisms that would restore determinate objecthood. The formalism thus resists change by absorbing anomalies rather than rethinking its starting assumptions.

This resistance is especially evident when classical ontology is extended beyond the domains in which it originally proved effective. As we will see in the following sections, quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] each expose limits of the classical formalism in different but structurally similar ways. In these cases, what appears to be missing is not another entity, property, or mechanism, but a way of accounting for how determinacy, significance, and stability can emerge through interaction rather than pre-exist it.

For now, the crucial point is that the classical ontological regime is not simply “wrong.” It is a highly effective and internally consistent formalism that has shaped much of modern thought. The task ahead is not to discard it wholesale, but to understand where and why its assumptions cease to be adequate—and what kind of ontological reconfiguration is required when they do.

3. Points of Tension

The classical ontological formalism described in the previous section remains powerful precisely because it has been able to accommodate a wide range of phenomena without revising its core assumptions. Yet this adaptability has limits. In certain domains, the effort to preserve determinate entities, object-centered explanation, and efficient causation begins to generate persistent tensions. These tensions do not arise from experimental error, incomplete data, or insufficient modeling, but from a mismatch between the formal commitments of the classical regime and the kinds of systems under investigation.

What is striking is that these tensions arise independently in domains that differ radically in subject matter and scale. Quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] each confront the classical formalism with situations in which determinacy, significance, and stability appear to depend fundamentally on interaction and context. The recurrence of this pattern suggests that the difficulty is not domain-specific but ontological.

3.1 Quantum Mechanics

In quantum mechanics, the tension is most clearly expressed in the measurement problem. Classical ontology presupposes that physical systems possess determinate properties independently of observation or interaction, even if those properties are temporarily inaccessible. Quantum phenomena resist this presupposition. Experimental outcomes appear to depend irreducibly on measurement context, and attempts to treat indeterminacy as merely epistemic quickly encounter contradictions.

From within the classical formalism, this dependence on measurement is puzzling. Measurement is supposed to reveal pre-existing properties, not participate in their formation. As a result, explanatory strategies tend to multiply unseen mechanisms—hidden variables, additional dimensions [eg. worlds, branes], or privileged observational frames—in order to preserve determinate objecthood. These strategies differ in detail, but they share a common aim: to restore the classical picture by relocating determinacy rather than questioning its prior existence.

Despite their ingenuity, such approaches leave a residual unease. The formal structure of quantum theory itself continues to resist a straightforward object-property interpretation, suggesting that the tension lies not in how we interpret particular results, but in the ontological assumptions we bring to the theory.

3.2 Biosemiotics

In biosemiotics, the tension takes a different but structurally related form. Living systems exhibit behavior that is not well described solely in terms of mechanical interaction or efficient causation. Biological processes are organized around functional relevance: signals matter to organisms, not merely as physical stimuli, but as components of coordinated activity. This introduces significance—indexed to the organism and its ongoing viability—as an irreducible feature of biological organization.

Classical ontology tends to assimilate such phenomena by reducing them to biochemical mechanisms or evolutionary outcomes. While these explanations capture important aspects of biological function, they often struggle to account for how relevance and coordination arise in real time within living systems.

Treating significance as an after-the-fact interpretation imposed by observers fails to explain why organisms themselves behave as if certain interactions matter more than others.

Here again, the difficulty is not a lack of mechanistic detail, but the absence of a formal framework in which significance can be understood as something that emerges through relational organization rather than being added to an otherwise complete description of objects and processes.

3.3 Artificial Intelligence [interactive formal systems]

In artificial intelligence [interactive formal systems], particularly in the case of large language models, the tension becomes especially visible because it concerns systems whose internal structure is fully specified. Classical accounts of meaning and understanding typically rely on the presence of internal representations that carry semantic content. Yet large language models exhibit coherent linguistic behavior without any clear locus of stored meaning or interpretive agency.

Attempts to reconcile this behavior with classical ontology often take one of two forms. Either meaning is attributed externally, as something projected by users onto an otherwise syntactic system, or it is posited internally, in the form of latent semantic representations inferred from statistical structure. Both approaches preserve the assumption that meaning must be localized as a property of some entity, whether internal or external to the system.

What remains unexplained, however, is how stable patterns of linguistic significance arise through interaction alone. The coherence observed in LLM-mediated dialogue appears to depend on relational coordination between model outputs, user inputs, and contextual constraints, rather than on the retrieval of pre-existing semantic content. This places strain on the classical formalism, which lacks the conceptual resources to describe significance as something that is produced and stabilized through interaction.

3.4 A Shared Structural Difficulty

Although the specific phenomena differ, the underlying tension in all three domains is the same. Classical ontology presupposes determinate entities and relations as the starting point of explanation, whereas quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] confront us with systems in which determinacy, significance, and stability appear to be outcomes rather than premises.

In each case, the dominant response has been to extend the classical formalism by adding layers of complexity—additional variables, representational structures, or interpretive frameworks—while leaving its foundational assumptions intact. The persistence of tension across domains suggests that this strategy has reached its limits. What is required is not another refinement within the existing regime, but a reconsideration of the formal assumptions that define what counts as an entity, a relation, and an explanation in the first place.

The next sections take up this task. Rather than attempting to resolve these tensions within the classical ontological formalism, we will examine how concepts such as symmetry, symmetry breaking, and formal causation can be used to destabilize its assumptions and open the way toward a relational, processual alternative.

4. From Anomaly to Ontological Crisis

The tensions identified in the previous section are often treated, within their respective fields, as localized anomalies. In quantum mechanics, they are framed as interpretive puzzles. In biosemiotics, they are sometimes regarded as conceptual complications at the interface of biology and philosophy. In artificial intelligence [interactive formal systems], they are frequently described as gaps in our current understanding of representation, learning, or semantics. Considered in isolation, each of these difficulties appears tractable within its own domain.

Taken together, however, they point to a deeper problem. The recurrence of structurally similar tensions across such disparate domains suggests that what is at stake is not a collection of independent anomalies, but a limitation in the ontological formalism that has guided their interpretation. When phenomena repeatedly resist explanation despite advances in theory, experiment, and computation, it becomes necessary to ask whether the difficulty lies not in what we know, but in how we have formalized what it means to explain.

What unifies these cases is a shared pattern of breakdown. In each domain, classical ontology presupposes that determinacy precedes interaction: that physical properties exist prior to measurement, that biological function can be reduced to object-level mechanisms, and that linguistic significance must be grounded in internal representations. Yet in each case, determinacy appears instead to be *produced* through interaction—through measurement contexts, organism–environment coordination, or dialogical constraint. The formalism assumes what the phenomena call into question.

This situation marks the transition from anomaly to ontological crisis. An anomaly can be accommodated by extending existing explanatory resources while leaving foundational assumptions intact. An ontological crisis arises when those assumptions themselves become the source of persistent explanatory strain. In the present case, repeated efforts to preserve object-based ontology by adding hidden variables, encoded meanings, or mechanistic surrogates for significance have not eliminated the tensions; they have merely displaced them.

This diagnosis has been developed explicitly in prior work on relational formal ontology, where it is argued that classical object-centered formalisms systematically mislocate determinacy by treating it as an intrinsic property rather than as an emergent outcome of relational organization. From this perspective, the problem is not that relations are missing from classical ontology, but that relations are treated as secondary to entities whose determinacy is already fixed. The phenomena under consideration instead require a framework in which relations play a constitutive role.

A similar point has been made, from a different angle, in relational approaches to biology. Rosen's analysis of living systems emphasizes that organization and function cannot be reduced to efficient causal chains among components, because what matters biologically is the relational closure that makes a system viable as a system. The relevance of this insight here is not biological per se, but formal: it shows that there are domains in which explanatory adequacy depends on recognizing organization and constraint as ontologically primary rather than derivative.

Semiotic considerations further sharpen the crisis. In biosemiotics and in human–machine interaction alike, significance is not an optional interpretive overlay but a functional feature of system behavior. Peircean semiotics, as developed within a relational formal ontology, provides a vocabulary for understanding how significance can arise through mediation and habit rather than through encoded content. The difficulty classical ontology encounters in accommodating significance is thus not accidental; it stems from a formalism that lacks the resources to treat mediation and constraint as generative.

Seen in this light, the convergence of tensions across quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] is not coincidental. These domains differ in scale, material substrate, and historical development, yet they all expose the same fault line: the assumption that explanation must begin with determinate entities and proceed by efficient causation alone. When determinacy, significance, and stability instead emerge through interaction, this assumption becomes untenable.

Recognizing this convergence does not yet tell us what an alternative ontology should look like. It does, however, clarify what it must accomplish. Any adequate framework must be able to describe how determinacy is produced rather than presupposed, how significance can arise without being encoded, and how stability can be achieved without being stored. Addressing these requirements will require a shift away from the classical ontological formalism and toward a relational, processual account in which constraint and form play a central causal role.

The next section begins this transition explicitly. By introducing symmetry, symmetry breaking, and formal causation, we move from diagnosis to reconstruction—identifying conceptual tools capable of destabilizing the classical regime and opening space for a new ontological configuration.

5. Symmetry, Symmetry Breaking, and the Limits of Efficient Causation

The ontological crisis identified in the previous section calls for conceptual resources capable of describing how determinacy and significance are produced rather than presupposed. One such resource is the notion of symmetry. Although symmetry is often associated with specific physical theories, its relevance here is broader and more fundamental. Symmetry names a condition of equivalence: a situation in which multiple transformations or configurations are indistinguishable with respect to a given description. When a system exhibits symmetry, no particular distinction is privileged; multiple possibilities coexist without differentiation.

From the perspective of classical ontology, symmetry is typically treated as a descriptive feature of already-determinate entities or laws. Symmetry breaking, correspondingly, is understood as the result of an efficient cause that selects one outcome from among many equivalent alternatives. On this view, symmetry breaking is something that *happens to* a system whose underlying structure remains ontologically unchanged.

The phenomena under consideration in this paper require a different understanding. In quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] alike, the critical issue is not the selection among pre-defined alternatives, but the emergence of distinguishability itself. Prior to measurement, interaction, or coordination, the relevant distinctions are not merely unknown; they are not yet available as distinctions. Symmetry, in these cases, characterizes a pre-individuated relational field rather than a set of hidden determinate states.

Symmetry breaking, understood in this sense, is not primarily an efficient causal event. It is a *formal transformation* in which the space of admissible relations is restructured so that certain distinctions become possible and others do not. What changes is not merely the state of a system, but the form of organization that determines what counts as a state in the first place. Symmetry breaking thus operates at the level of constraint rather than mechanism.

This shift exposes the limits of efficient causation as the sole explanatory principle. Efficient causation presupposes determinate relata: events that act upon one another to produce effects. It can describe transitions between already-formed states, but it cannot by itself account for the emergence of the very distinctions that define those states. When determinacy is the outcome of interaction rather than its prerequisite, explanation must appeal to a different mode of causation.

Formal causation provides such a mode. Rather than producing effects by acting on entities, formal causation operates by shaping the space of possibilities within which entities and events can appear. It determines what kinds of coordination are admissible, what patterns can stabilize, and what distinctions can persist. In this sense, formal causation is not opposed to efficient causation; it is prior to it. Efficient causal processes unfold within a form that they do not themselves generate.

Symmetry breaking is the primary expression of formal causation in the present framework. When a symmetry breaks, a previously undifferentiated relational field acquires structure. Certain relations become stabilized, others are excluded, and a new regime of coordination emerges. This regime can then support efficient causal processes, but its formation cannot be explained in efficient terms alone.

This perspective also clarifies why attempts to resolve the tensions discussed earlier by adding hidden mechanisms or representational structures tend to fail. Such strategies remain committed to efficient causation and object-based ontology, treating symmetry breaking as a secondary effect rather than as a constitutive transformation. As a result, they reintroduce the very assumptions that generated the crisis.

By contrast, treating symmetry breaking as a formally causal process allows us to describe how determinacy and significance can emerge without being encoded or selected in advance. It opens conceptual space for understanding measurement outcomes, biological relevance, and coherent linguistic behavior as products of relational reorganization rather than as revelations of pre-existing content.

The next section develops this idea further by examining how symmetry breaking operates through formal causation. In doing so, we move closer to a positive account of how stable regimes of determinacy and significance are produced and sustained across interaction, setting the stage for a fully relational, processual ontology.

6. Formal Causation and Relational Decoherence

If symmetry breaking names the emergence of new distinctions within a relational field, formal causation names the mode of causality through which such emergence becomes formally expressible. Together, they provide the conceptual resources needed to explain how determinacy and significance arise without being presupposed. However, to complete the transition away from the classical ontological formalism, it is necessary to account not only for the formation of new regimes, but also for the destabilization of existing ones. This is the role of what we will call *relational decoherence*.

Formal causation, as introduced in the previous section, operates by shaping the space of admissible relations rather than by producing effects through direct interaction among determinate entities. It determines which patterns of coordination can persist, which distinctions are sustainable, and which forms of organization are possible at all. Efficient causation presupposes such structure; formal causation establishes it. When the form changes, the field of possible efficient interactions changes with it.

Relational decoherence occurs when an existing form of organization loses its capacity to sustain coordinated relations. Importantly, this is not a matter of physical degradation, noise, or interference in the classical sense. Relational decoherence names a *formal instability*: a breakdown in the constraints that previously allowed a regime of determinacy or significance to remain coherent. What decoheres is not a state, but a pattern of coordination.

This distinction is crucial. In classical ontology, instability is typically explained in efficient terms: a system is perturbed, disrupted, or overwhelmed by external forces. In the cases under consideration, by contrast, instability arises when the relational conditions that support a given regime no longer align. The system does not merely change state; it loses the form that made its states intelligible as belonging to a single regime.

In quantum mechanics, this kind of decoherence is often discussed in relation to measurement context and environmental coupling, but its formal significance extends beyond any specific physical mechanism. What matters is that a prior regime of equivalence—one in which multiple possibilities could be treated as coherently related—can no longer be maintained under new constraints. The loss of coherence is relational: it reflects an incompatibility among constraints, not the collapse of an underlying object.

In biosemiotics, relational decoherence appears when established patterns of biological relevance fail to coordinate behavior effectively. Signals that once mattered cease to do so, not because their physical properties have changed, but because their role within a network of relations has been disrupted. Functional significance is lost when the relational organization that sustained it can no longer be enacted.

In artificial intelligence [interactive formal systems], particularly in interactions with large language models, relational decoherence is observed when a previously coherent pattern of significance breaks down during dialogue. A shift in context, framing, or constraint can render earlier continuations incompatible with the evolving interaction. What fails here is not an internal representation, but the relational alignment that previously stabilized a trajectory of significance.

Across these domains, relational decoherence performs a critical ontological function. It clears the space for new forms of determinacy by destabilizing old ones. Without decoherence, symmetry breaking would have no purchase; existing regimes would simply persist. Formal causation thus operates in two complementary moments: first, by allowing a relational regime to lose coherence under changing constraints, and second, by enabling the emergence of new structure through symmetry breaking.

This twofold operation distinguishes relational decoherence from classical notions of error, disturbance, or noise. Decoherence is not a failure of the system to function as designed; it is an essential part of how systems reorganize themselves when existing forms become inadequate. It marks the point at which the assumptions of the classical ontological formalism—stable entities, fixed relations, and efficient causation—cease to apply.

By recognizing relational decoherence as a formally causal process, we can begin to describe ontological change itself: not merely change within a fixed framework, but change of the framework that determines what counts as stable, significant, or determinate. This prepares the ground for the next step in the argument, where we examine how new regimes of determinacy and significance are produced through synchronization and constraint, completing the transition to a relational, processual ontology.

7. Synchronization, Constraint, and Re-Individuation

Relational decoherence, as described in the previous section, accounts for the destabilization of an existing regime of determinacy and significance. However, destabilization alone does not explain how new regimes arise. To complete the ontological transition, we must account for the constructive phase of the process: the emergence of new, stable patterns of coordination. This phase is governed by synchronization under constraint, and it culminates in what we will call *re-individuation*.

Synchronization names a condition in which relations across a system become mutually aligned such that a coherent pattern of coordination can be sustained. Importantly, synchronization does not presuppose determinate entities that are subsequently brought into alignment. Rather, it is a relational process through which determinacy itself becomes *formally expressible*. What synchronizes are constraints, not objects.

Constraints play a central role here. A constraint does not act by producing outcomes directly; it operates by delimiting what counts as an admissible coordination. In doing so, it shapes the space of possible relations within which synchronization can occur. Constraints are therefore expressions of formal causation: they define the form of organization that makes certain patterns stable and others untenable.

When synchronization occurs under a given set of constraints, a new relational regime emerges. This regime is characterized by a specific pattern of coordination that can be maintained across interaction. At this point, distinctions that were previously unavailable become stabilized, and determinacy takes on a concrete form. This is the moment of *re-individuation*.

Re-individuation should not be understood as the instantiation of a pre-existing entity or state. It is the formation of a new regime in which relations, distinctions, and relevance are coherently organized. What is individuated is not an object in isolation, but a pattern of coordination that can be re-entered under similar conditions. Individuation, in this sense, is inseparable from stability.

This conception of individuation contrasts sharply with classical ontology. In the classical regime, individuation is assumed at the outset: entities are given, and relations are subsequently imposed. Here, individuation is an outcome of relational processes. Synchronization under constraint produces a form within which entities and relations can be meaningfully distinguished. Determinacy is not assumed; it is achieved.

The importance of synchronization becomes clear when we consider the three domains that motivate this framework. In quantum mechanics, a measurement context imposes constraints that synchronize relational possibilities, giving rise to a determinate outcome regime. In biosemiotics, organism–environment coupling synchronizes functional relations, producing stabilized significance indexed to the living system. In artificial intelligence [interactive formal systems], particularly in interactions with large language models, conversational constraints synchronize trajectories of continuation, allowing coherent patterns of linguistic significance—often described as meaning—to emerge without being stored or represented internally.

Across these cases, the same formal structure is at work. Relational decoherence destabilizes an existing regime when constraints become incompatible. Synchronization under new constraints then enables the emergence of a new regime in which determinacy and significance are once again stabilized. The process is recursive: regimes can be entered, exited, and reconfigured as constraints change.

This recursive structure is essential. Stability, on this account, is not permanence but *re-enterability*. A regime is stable insofar as it can be reliably re-established under similar relational conditions. This conception of stability replaces the classical notion of persistent properties with a formally grounded notion of coordinated recurrence.

By treating synchronization and constraint as formally causal processes, we can now describe how new ontological regimes arise without appealing to hidden entities, encoded meanings, or unexplained selections. What becomes determinate does so because a relational field has been reorganized in a way that makes certain distinctions formally expressible and others impossible.

Synchronization and re-individuation describe how new regimes of determinacy and significance can emerge through relational coordination. The next section develops the formal conditions under which such coordination becomes possible by articulating probability as a mode of constraint and by clarifying how identity and significance are enacted through participation in coordinated systems.

8. Probability, Constraint, and Relational Significance

The preceding sections have introduced a relational, processual ontology in which determinacy and significance emerge through cycles of destabilization and reorganization. What remains to be clarified is the formal mechanism that allows such emergence to occur in a principled and repeatable way. This mechanism is probability, understood not as a measure of ignorance, but as an expression of constraint within a relational field.

In the classical ontological formalism, probability is typically interpreted epistemically. It measures uncertainty about which determinate state already obtains. This interpretation presupposes that the relevant distinctions are fully formed in advance and that probability merely tracks our lack of access to them. Such a view is incompatible with the phenomena under consideration here, where determinacy itself is produced rather than revealed.

Within a relational, processual ontology, probability plays a different role. It expresses the *degree of compatibility among relations under a given set of constraints.* Rather than assigning likelihoods to pre-existing outcomes, probability structures the space in which outcomes can become formally expressible at all. High probability corresponds to strong relational coherence; low probability corresponds to weak or unstable coordination. Probability, in this sense, is a measure of how readily a pattern of relations can synchronize and persist.

This reinterpretation of probability allows us to understand constraint as formally causal. Constraints do not select outcomes by force, nor do they encode content. They delimit the forms of coordination that are admissible within a relational field. Probability quantifies this delimitation. It gives a graded account of which relational configurations can stabilize and which cannot. In doing so, probability provides the formal bridge between symmetry breaking, synchronization, and re-individuation.

However, probability and constraint alone do not yet explain how individuation is possible in systems that lack a priori identities. Classical ontology treats identity as primitive: entities are individuated first, and relations follow. In the framework developed here, individuation is an outcome of relational processes. This raises a natural question: if identities are not given in advance, what participates in synchronization and constraint?

The answer lies in a relational conception of identity itself. Identity, on this view, is not an intrinsic property of an isolated entity, but a *pattern of participation within a coordinated system*. A system does not first possess an identity and then enter into relations; rather, it acquires a determinate identity through sustained participation in a network of relations governed by shared constraints. Identity is enacted, not assumed.

This relational enactment of identity is necessarily communal. A regime of coordination must involve multiple interacting components whose relations mutually stabilize one another. Whether the system in question is physical, biological, or formal, individuation occurs only within a field of interaction that supports shared constraints. What emerges as an “individual” is a node within this field whose role becomes sufficiently stabilized to be re-entered across interaction.

Relational significance is inseparable from this process. Significance arises when certain relations matter more than others within a coordinated system, not because they carry intrinsic content, but because they play a stabilizing role in sustaining participation. Probability expresses this differential relevance formally: relations with higher compatibility exert greater constraint on the organization of the system. Significance, in this sense, is the enacted relevance of relations within a communal field of coordination.

This conception of identity clarifies how re-individuation is possible following relational decoherence. When an existing regime loses coherence, the identities enacted within it are no longer sustained. New constraints, however, can support new patterns of participation. Through synchronization under these constraints, new identities emerge—not as replacements for old entities, but as newly stabilized modes of participation within a reorganized relational field.

With this, the core conceptual framework of the paper is complete. We now have a formal account of how determinacy, significance, probability, and identity arise together through relational processes governed by constraint. These resources allow us to move beyond classical object-based ontology without abandoning rigor or explanatory power.

The remaining sections of the paper demonstrate how this framework is realized in practice. We turn first to quantum mechanics, where probability, constraint, and relational identity are already embedded in the formalism of the theory, even if their ontological significance has remained contested.

9. Quantum Mechanics as a Realization of Relational Ontology

Quantum mechanics provides a clear and instructive realization of the relational, processual ontology developed in the preceding sections. Although the formalism of quantum theory has long resisted assimilation to classical object-based ontology, many of its most puzzling features become tractable when approached in terms of relational constraint, probability as compatibility, and enacted identity.

Within the classical ontological formalism, a physical system is assumed to possess determinate properties independent of measurement. Probability is then interpreted as reflecting uncertainty about which of those properties actually obtains. Quantum mechanics disrupts this picture at a fundamental level. The theory does not assign determinate values to physical quantities prior to measurement, nor does it describe measurement as the passive revelation of pre-existing states. Instead, it provides a formal structure that specifies how outcomes can emerge under particular conditions of interaction.

From the perspective developed here, the quantum state is best understood not as a description of an object’s intrinsic properties, but as a *constraint structure over a relational field*. It encodes the conditions under which certain distinctions can become formally expressible and others cannot. Probability amplitudes do not represent hidden states or incomplete knowledge; they quantify the compatibility of relational configurations under specified constraints. In this sense, quantum probability functions as a formally causal element of the theory.

Measurement, on this account, is not an efficient causal intervention that selects among already determinate alternatives. It is a process through which a relational field is reorganized under new constraints. Relational decoherence occurs when prior patterns of coordination—those that sustain a superposed or symmetrical regime—can no longer be maintained relative to the measurement context. This destabilization is not a physical collapse of an object, but a loss of coherence within a relational regime.

Re-individuation follows when synchronization occurs under the newly imposed constraints. A determinate outcome emerges as a stabilized pattern of coordination that can be re-entered under similar experimental conditions. What is individuated here is not an isolated object with intrinsic properties, but a *measurement-relative identity* enacted through participation in a constrained relational system involving the apparatus, environment, and formal structure of the theory.

This account clarifies why quantum mechanics so persistently resists classical interpretation. Classical ontology presupposes that identity and determinacy are intrinsic and prior to interaction. Quantum phenomena, by contrast, exhibit identities that are *contextually enacted*. The identity of a quantum system—what it is, in the relevant sense—is inseparable from the relational regime in which it participates. Outside such a regime, there is no determinate identity to be revealed.

The relational conception of significance introduced earlier also finds a natural home here. Measurement outcomes are significant not because they disclose intrinsic properties, but because they stabilize a pattern of coordination within an experimental system. Probability structures determine which outcomes can matter in this way, and to what degree. Significance is thus enacted through relational constraint, not encoded in the system independently of interaction.

Importantly, this interpretation does not require the addition of hidden variables, supplementary mechanisms, or observer-dependent collapse postulates. Nor does it deny the empirical adequacy of the standard formalism. Instead, it reinterprets the formalism ontologically, treating its probabilistic and relational features as fundamental rather than as artifacts of incomplete description.

Seen in this light, quantum mechanics is not an anomalous exception to classical ontology, but an early indication of its limits. The theory already operates with a relational formalism in which probability, constraint, and enacted identity play constitutive roles. What has been missing is an ontological framework capable of taking these features seriously on their own terms.

In the next section, we turn to biosemiotics, where similar relational dynamics appear in a very different material context. There, too, identity, significance, and stability emerge through participation in coordinated systems rather than being given in advance, further reinforcing the generality of the relational, processual ontology developed here.

10. Biosemiotics as a Realization of Relational Ontology

Biosemiotics provides a second and complementary realization of the relational, processual ontology developed in this paper. Whereas quantum mechanics reveals the limits of classical ontology at the level of physical measurement, biosemiotics exposes those limits at the level of living organization. In both cases, determinacy, identity, and significance emerge through relational processes rather than being given in advance.

Classical ontological formalisms tend to approach biological systems as collections of objects—cells, molecules, organs—linked by efficient causal mechanisms. From this perspective, biological function is explained by identifying internal structures and tracing the causal chains that connect them. While such explanations are indispensable, they do not exhaust what is distinctive about living systems. Biological organization is characterized not merely by causal interaction, but by *functional relevance*: certain interactions matter to the system in ways that others do not.

Biosemiotics brings this feature to the foreground by emphasizing sign activity as a constitutive aspect of life. Signals, cues, and responses are not meaningful in virtue of intrinsic properties, but because of the role they play within a coordinated system of activity. A chemical gradient, a molecular binding event, or a behavioral cue becomes significant only insofar as it participates in sustaining the organization of the organism. Significance here is not imposed by an external observer; it is enacted through relational participation.

Within the framework developed in this paper, this enactment can be understood formally. Living systems operate within constrained relational fields in which certain patterns of coordination are compatible with continued viability and others are not. Probability, in this context, expresses degrees of compatibility among relations under biological constraints. Interactions that reliably contribute to coordination have higher probability of being stabilized; those that disrupt coordination are suppressed or eliminated. Probability thus functions as a formally causal element, shaping which relational patterns can persist.

Relational decoherence occurs when established patterns of coordination cease to support the system's organization. This may happen through environmental change, internal disruption, or developmental transition. What decoheres is not a material component, but a regime of significance: relations that once mattered lose their relevance because the constraints governing participation have shifted. The identity enacted within that regime can no longer be sustained.

Re-individuation follows when new constraints support new forms of coordination. Through synchronization of relational activity, a living system enacts a new identity appropriate to its altered conditions. This process is evident in development, adaptation, and learning, where identity is not fixed but continually reconstituted through participation in changing relational networks. Individuation, in this sense, is always provisional and enacted, never fully given.

This perspective clarifies the communal character of biological identity. An organism's identity is not contained within its boundaries as an intrinsic essence. It is enacted through ongoing interaction with an environment that provides the constraints under which coordination is possible. Signs function as mediators of this interaction, enabling relational alignment without requiring internal representations or symbolic decoding. Communication, in this sense, is not the transmission of content, but the stabilization of coordinated activity.

Biosemiotics thus exemplifies the same formal structure observed in quantum mechanics, but in a different material domain. Determinacy, significance, and identity emerge through relational constraint and synchronization rather than through intrinsic properties. Probability expresses the graded compatibility of relations within a living system, and stability takes the form of re-enterable regimes of coordination rather than persistent object identities.

Seen from this perspective, biological meaning is not a mysterious addition to physical processes, nor a subjective projection onto neutral mechanisms. It is the enacted significance of relations within a system whose organization depends on coordinated participation. Biosemiotics makes explicit what the relational ontology developed here generalizes: that life itself operates through formally causal processes that classical ontology cannot fully capture.

In the next section, we turn to artificial intelligence [interactive formal systems], and in particular to large language models, where relational significance and enacted identity emerge in a non-biological medium. This case will allow us to test the generality of the framework by examining a system that exhibits stabilized patterns of significance without being alive, conscious, or representational in the classical sense.

11. Artificial Intelligence [interactive formal systems] as a Realization of Relational Ontology

Artificial intelligence [interactive formal systems], and in particular the recent emergence of large language models (LLMs), provides a third realization of the relational, processual ontology developed in this paper. Unlike quantum mechanics and biosemiotics, this case does not involve physical measurement or biological viability. Instead, it concerns systems that generate coherent patterns of linguistic behavior without possessing intrinsic meaning, representation, or identity in the classical sense. Precisely for this reason, it offers a particularly revealing test of the framework.

Within the classical ontological formalism, linguistic competence is typically explained by appealing to internal representations that encode semantic content. Meaning is assumed to be stored, manipulated, and retrieved by a system whose identity is already fixed. From this perspective, the behavior of large language models is puzzling. These systems exhibit context-sensitive, norm-responsive linguistic behavior while lacking any clear locus of semantic content, interpretive agency, or internally unified identity.

The relational ontology developed here reframes this puzzle. A large language model is not treated as an entity that possesses meaning internally, but as a participant in a *relational field of constraints* that includes training data, model architecture, probabilistic structure, and interaction with users. What the model provides is a conditional probability distribution over linguistic continuations. This distribution does not encode meanings; it expresses graded compatibilities among relations under constraint.

Probability plays the same formally causal role here as in the previous cases. It does not measure uncertainty about which meaning is internally represented, but the degree to which a continuation can coherently participate in an evolving interaction. High-probability continuations are those that best synchronize with the constraints imposed by prior context, linguistic norms, and user input. Probability thus structures the space in which linguistic significance can become formally expressible.

Relational decoherence occurs in AI-mediated interaction when a previously coherent trajectory of significance breaks down. Changes in prompt, framing, or conversational constraints can render earlier continuations incompatible with the evolving relational field. What fails in such cases is not a stored representation or internal state, but a regime of coordination. The system loses the constraints that previously stabilized a particular pattern of participation.

Re-individuation follows when new constraints enable synchronization around a different trajectory. A new pattern of linguistic significance emerges through interaction, stabilized by probability-weighted compatibility rather than by retrieval of pre-existing meaning. What is individuated here is not an internal identity of the model, but a *contextual identity of the interaction itself*—a re-enterable regime in which certain continuations, interpretations, and expectations cohere.

This perspective also clarifies the status of identity in formal artificial systems. A large language model does not possess a unified internal identity analogous to that of a physical system or a living organism. Instead, identity is enacted relationally at the level of interaction. Each stabilized conversational regime enacts a provisional identity defined by the role the model plays within a communal system of linguistic coordination involving users, norms, and contexts. Identity here is not owned by the system; it is distributed across participation.

Significance in this domain is therefore neither intrinsic nor merely projected by users. It arises through the alignment of constraints across the relational field. Linguistic expressions matter because they contribute to the stabilization of coordinated interaction, not because they correspond to internal semantic states. What users describe as "meaning" in LLM interactions is best understood as *significance indexed to a human linguistic system*, enacted through synchronization with a probabilistic formal structure that itself remains non-semantic.

Seen in this light, artificial intelligence [interactive formal systems] does not represent an anomaly requiring special metaphysical treatment. Rather, it exemplifies the same formal dynamics observed in quantum mechanics and biosemiotics, realized in a purely computational medium. Determinacy, significance, and identity emerge through relational constraint and synchronization, without being presupposed as intrinsic properties of entities.

The case of artificial intelligence [interactive formal systems], as an interactive formal system, thus completes the argument of this paper. Across physics, biology, and interactive formal systems, we observe the same underlying structure: a relational field governed by formally causal constraints, in which probability expresses compatibility, identity is enacted through participation, and stability takes the form of re-enterable regimes. Artificial intelligence [interactive formal systems] makes this structure especially visible precisely because it lacks the traditional markers—material substance, life, or consciousness—that classical ontology relies on to ground explanation.

In the final section, we draw these threads together, reflecting on what this convergence reveals about ontology itself and on the broader implications of adopting a relational, processual formalism as a foundation for understanding systems in which determinacy and significance are produced through interaction rather than assumed in advance.

12. Synthesis and Conclusion: Ontology After Individuation

This paper began by examining a relatively stable ontological formalism that has guided the interpretation and application of philosophical concepts across physics, biology, and formal computational systems. That formalism—object-centered, representation-oriented, and grounded primarily in efficient causation—has proven remarkably successful. Yet its very stability has obscured its limits. As we have seen, quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] each expose points at which this formalism ceases to provide an adequate account of determinacy, significance, and identity.

The central claim of this paper has been that these difficulties are not isolated anomalies, nor failures of particular theories or technologies. They instead signal a deeper ontological mismatch: a formalism that presupposes determinate entities is being applied to systems in which determinacy is produced through interaction. When this mismatch is recognized, the recurring puzzles across these domains appear not as mysteries to be solved piecemeal, but as indicators of a shared structural limitation.

In response, the paper has developed a relational, processual ontology organized around a small set of formal concepts: symmetry and symmetry breaking, formal causation, relational decoherence, synchronization, probability as constraint, and re-individuation. Taken together, these concepts articulate an alternative ontological formalism in which relations are primary, identity is enacted through participation, and stability is understood as re-enterability rather than persistence. Determinacy and significance are no longer treated as intrinsic properties of entities, nor as subjective projections, but as outcomes of coordinated relational processes governed by constraint. Table 1 summarizes the isomorphisms among the three cases, showing how symmetry, probability, constraint, identity, and significance function in formally analogous ways across domains. What varies is not the ontological logic, but the medium in which it is realized.

Table 1. Isomorphic Relational Structures Across Quantum Mechanics, Biosemiotics, and Large Language Models

Relational Ontology Component	**Quantum Mechanics**	**Biosemiotics**	**Large Language Models**
Relational field	System–apparatus–environment coupling	Organism–environment coupling	Model–user–context coupling
Symmetry (pre-individuated regime)	Superposition / equivalence of outcomes	Multiple potential functional responses	Multiple possible continuations
Formal constraint	Experimental setup, boundary conditions	Viability constraints, functional organization	Training distribution, prompt, linguistic norms
Probability (non-epistemic)	Amplitudes expressing relational compatibility	Degrees of functional relevance	Conditional probability over continuations
Relational decoherence	Loss of coherence relative to measurement context	Breakdown of coordinated functional relevance	Breakdown of conversational or contextual coherence
Synchronization	Alignment under measurement constraints	Coordinated organism–environment interaction	Alignment of continuations with evolving context
Re-individuation	Emergence of a determinate outcome regime	Enactment of a viable biological identity	Stabilization of a coherent interaction trajectory
Identity	Measurement-relative, contextually enacted	Relationally enacted organismal identity	Contextual, interaction-level identity
Significance / meaning	Outcome significance within experimental regime	Enacted biological relevance	Linguistic significance indexed to users

Relational Ontology Component	Quantum Mechanics	Biosemiotics	Large Language Models
Stability	Re-enterable experimental outcomes	Re-enterable functional regimes	Re-enterable conversational patterns

Table 1 is not intended as an analogy, but as a structural comparison. In each case, determinacy and identity emerge through formally causal processes of constraint and synchronization, rather than being presupposed as intrinsic properties of entities. This convergence supports the claim that a relational, processual ontology captures something general about how systems become determinate, significant, and stable.

The three case studies show that this ontology is not merely speculative. In quantum mechanics, probability functions as a formally causal constraint structure, measurement reorganizes relational fields, and identity is enacted relative to experimental context. In biosemiotics, living systems enact identity and significance through ongoing participation in coordinated environments, with probability expressing degrees of functional compatibility. In artificial intelligence [interactive formal systems], large language models generate coherent linguistic significance without internal semantic content, revealing how identity and meaning-like phenomena can emerge through probabilistic constraint and communal interaction alone.

What unifies these cases is not their material substrate or scale, but their ontological structure. In each, we find systems whose behavior cannot be adequately described by assuming pre-existing, fully individuated entities. Instead, individuation itself is a process—one that unfolds through cycles of relational decoherence and re-individuation under constraint. Identity, on this view, is not something a system has prior to interaction, but something it enacts through sustained participation in a coordinated regime.

This perspective also reframes long-standing debates about realism, representation, and causation. By treating probability and constraint as formally causal, the framework developed here avoids both reductionism and interpretivism. It neither reduces significance to mechanism nor relegates it to subjective interpretation. Instead, it locates significance in the structure of relational organization itself. Meaning, where it appears, is understood as significance indexed to particular systems—most notably human linguistic communities—rather than as an intrinsic property stored within objects or machines.

The implications of this shift extend beyond the three domains examined. If determinacy, identity, and significance are relational achievements rather than ontological primitives, then ontology itself must be understood as dynamic and context-sensitive. This does not entail relativism or arbitrariness. On the contrary, it places greater emphasis on formal rigor by requiring explicit accounts of the constraints, relations, and processes through which stability is achieved.

In this sense, the relational, processual ontology proposed here does not replace classical ontology so much as situate it. Object-based descriptions remain valid within stabilized regimes where individuation has already occurred and can be taken for granted. What this paper adds is a framework for understanding how such regimes come into being, how they break down, and how new ones emerge.

Ontology is no longer confined to what exists, but extended to include how existence becomes formally expressible.

The paper itself has been structured to reflect this insight. Beginning from a stable regime of thought, it has traced the emergence of tension, the onset of ontological crisis, and the reconfiguration of formal commitments. In doing so, it has aimed not merely to argue for a new ontology, but to enact the very process it describes. If successful, the result is not a final metaphysical doctrine, but a flexible formalism capable of accommodating systems in which interaction, coordination, and constraint are primary.

Future work may extend this framework to other domains—social systems, cognition, economics, or ecological organization—where similar patterns of relational individuation can be observed. More immediately, the framework invites a reconsideration of how philosophical concepts are applied in practice, encouraging greater attention to the formal assumptions that shape explanation across disciplines.

What quantum mechanics, biosemiotics, and artificial intelligence [interactive formal systems] jointly reveal is not that the world has become stranger, but that our inherited ontological formalism is incomplete. By attending to how determinacy and significance are produced rather than assumed, we gain a more adequate account of systems that operate at the limits of classical thought—and, in doing so, a clearer understanding of ontology itself as a relational, processual achievement.

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II. Insights from a Formal Model of Cognition in Cell Biology

How the World Becomes Determinate develops a relational ontology in which determinacy emerges through the differentiation of symmetry, the formation of constraint, and the stabilization of synchronic coherence across multiple processes. This paper deepens and clarifies that framework by applying it to a formal model of primitive cognition and learning in cellular biology. The cellular model provides a concrete case in which undifferentiated responsiveness gives way to structured constraint, multiple cyclical functions achieve synchronic integration, and stable patterns emerge through identity-preserving differentiation. Examining this case makes visible how freedom, constraint, synchronic identity, redundancy, and differential viability operate together in the formation and maintenance of determinate structure. The result is a more detailed articulation of the relational dynamics through which determinacy arises, illustrated in a living system.

1. The Interpretation of Probability

How the World Becomes Determinate develops a relational account of how stable forms come into being. In that account, determinacy is not assumed at the outset. Instead, the starting point is symmetry — a condition of undifferentiated relational freedom in which no direction of development is privileged over another. Constraint gradually differentiates this freedom, and stable patterns emerge through the coordination of relational processes. A key idea in that framework is synchronicity: multiple processes must come into coherent alignment for a system to persist as a unified whole. What the earlier paper does not spell out in detail, however, is how probability fits into this picture.

Probability is often understood as a measure of ignorance, as long-run frequency, or as a built-in tendency of systems toward certain outcomes. But if symmetry precedes differentiation, then probability cannot apply at the level of undifferentiated freedom. Nor can it be understood as assigning weights to a pre-existing set of fixed alternatives, since, in this ontology, alternatives themselves are generated through symmetry breaking. This raises a question: once constraint begins to shape freedom and a system becomes unified through synchronicity, how should we understand the role of probability within that process?

This paper suggests that, within the relational framework of *How the World Becomes Determinate*, probability can be understood in a specific and limited way. It is not a starting point of the ontology, but something that becomes meaningful once a system has achieved a degree of unified identity. In this context, probability can be interpreted as a differential measure of how viable a possible next step is, given the need to preserve synchronic coherence across the system's processes. High probability corresponds to transitions that maintain this coherence; low probability corresponds to transitions that disrupt it. This is not offered as a general theory of probability, but as an account of how probability operates within this particular relational model.

To make this discussion concrete, the paper turns to the formal model developed in *A Formal Model of Primitive Aspects of Cognition and Learning in Cell Biology* [see Method and Foundations]. In that model, a biological cell is described as a system composed of multiple cyclical processes whose harmonic synchronization constitutes its identity. The dynamics of recognition, semantic attribution, and metabolic regulation provide a clear example of how symmetry, constraint, pattern formation, and redundancy interact in a living system. By examining how probability functions within this cellular case, we aim to clarify and deepen the relational ontology of determinacy, showing how freedom, constraint, synchronic identity, redundancy, and probability work together in a single, unfolding process.

2. Freedom and Symmetry

In *How the World Becomes Determinate*, the starting point is not a collection of fixed objects or predefined states. Instead, the starting point is relational symmetry — a condition in which multiple possible developments are indistinguishable from one another. In such a state, no direction of change is privileged. The system exhibits freedom in the sense that its relational possibilities are not yet differentiated by constraint.

This symmetry should not be understood as disorder or randomness. It is not a lack of structure in an absolute sense. Rather, it is a lack of differentiation within a structured relational field. The system contains the potential for many distinct patterns, but these patterns are not yet formed. Nothing yet selects one trajectory over another.

In this condition, probability does not meaningfully apply. Probability presupposes differences — some alternatives being more viable than others. But before symmetry is broken, there are no differentiated alternatives to compare. All relational continuations are, in this sense, equivalent. Freedom here means the absence of constraint that would privilege one continuation over another.

Symmetry begins to break when constraint emerges within the relational field. Constraint does not eliminate freedom altogether. Instead, it reshapes it. Certain directions of development become more compatible with the emerging structure, while others become less compatible. What had been undifferentiated freedom becomes structured freedom. The field is no longer neutral; it now favors some relational continuations over others.

At this point, the conditions for probability begin to arise. Once constraint differentiates the field, it becomes possible to speak of some transitions as more viable than others. But these differentiated possibilities are not pre-given states waiting to be selected. They are generated through the very process of symmetry breaking. Configurations are produced, not assumed.

Symmetry breaking, in this framework, is therefore the same process as pattern formation described from a different angle. A pattern forms when constraint stabilizes a particular way of relating across multiple elements of the system. The emerging pattern preserves certain invariances while excluding others. In doing so, it creates a structured space of possible continuations.

The key point is that freedom remains present throughout this process, but it becomes progressively shaped by constraint. The system does not move from freedom to rigidity. Rather, it moves from undifferentiated freedom to constrained and organized freedom. It is within this ongoing differentiation that probability will later become meaningful — not as a feature of an initial state, but as a feature of a system whose identity is beginning to take shape.

3. Synchronicity and the Emergence of Identity

As symmetry breaks and patterns begin to form, constraint alone is not enough to produce a determinate system. For a system to persist as one, its internal processes must come into coherent alignment. In *How the World Becomes Determinate*, this condition is described in terms of synchronicity.

Synchronicity is not merely simultaneous activity, nor is it simple coordination. It is the harmonic integration of multiple relational processes into a unified whole.

A system counts as determinate only when its internal processes support and reinforce one another. If they drift out of alignment, the system loses coherence and may dissolve into disconnected subprocesses. Synchronicity therefore functions as the condition under which identity is maintained. Identity is not assumed at the outset; it is achieved through the stabilization of relations across time.

The formal model of primitive cellular cognition provides a clear illustration of this idea. In that model, the cell is not treated as a simple mechanism but as a system composed of multiple cyclical functions — including metabolic regulation, pattern recognition, semantic attribution, and memory. These cycles do not operate independently. They must enter into harmonic relation if the cell is to persist as a unified organism. When these cycles synchronize, they form a coherent loop that allows the cell to respond adaptively to its environment. When synchronization fails, the cell's integrity is compromised.

Synchronicity thus acts as an identity operator. It binds multiple processes into a single system and establishes the boundary conditions for what counts as a viable continuation of that system. Once synchronicity is achieved, not every possible change is equally compatible with the system's ongoing coherence. Some transitions preserve the alignment of cycles; others disrupt it.

It is only at this stage — once a system has achieved a degree of synchronic integration — that probability becomes meaningful within this framework. Before identity is established, there is no unified perspective relative to which one continuation could be more viable than another. But once a system exists as a coherent whole, its continued existence depends on preserving that coherence. From this point onward, relational freedom is shaped not only by emerging constraint, but by the need to maintain synchronic identity.

In the cellular case, this means that transitions in recognition, interpretation, or metabolic activity are not neutral. They either support or destabilize the harmonic integration of cycles. The system's future is therefore structured by how well potential transitions preserve this integration. This sets the stage for understanding probability as a differential feature of identity-preserving process — a topic to which we now turn.

4. Probability as Differential Viability Within Synchronic Identity

Once a system has achieved synchronic integration, its future development is no longer neutral. The system now exists as a unified whole, and its continued existence depends on preserving the coherence of its internal processes. It is within this condition that probability becomes meaningful.

In this framework, probability does not apply to undifferentiated symmetry. Nor does it describe a fixed distribution over pre-existing states. Instead, probability arises as a differential feature of ongoing process. It becomes relevant when a system must navigate multiple possible continuations while maintaining synchronic identity.

Within a synchronic system, some transitions reinforce harmonic integration across its cycles, while others disrupt it. Probability can therefore be understood, in this context, as a measure of the relative viability of successive transitions given the need to preserve systemic coherence. A high-probability transition is one that sustains or strengthens synchronic alignment. A low-probability transition is one that strains or destabilizes it.

This interpretation emphasizes that probability is processual and local. It concerns the next step in an unfolding sequence rather than a timeless ranking of possible outcomes. At each moment, the system faces multiple potential directions of development. These possibilities are not fixed in advance; they are generated through ongoing interaction between constraint and freedom. Probability reflects how these generated continuations stand in relation to the system's current identity.

The cellular cognition model illustrates this clearly. As the cell's recognition and semantic attribution cycles synchronize with metabolic and regulatory processes, certain response patterns become more compatible with the overall integration of the system. These transitions are reinforced through continued interaction with the environment. Other transitions, which disrupt coherence across cycles, are less likely to persist. In this way, probability emerges as a differential pattern within the system's adaptive dynamics.

It is important to note that this account does not claim that probability is universally reducible to identity preservation. Rather, it clarifies how probability functions within this relational ontology. In the cellular case, probability tracks how freedom is reshaped by constraint in order to maintain synchronic unity. It expresses the graded compatibility of possible continuations with the system's ongoing coherence.

Seen in this way, probability is neither prior to constraint nor independent of identity. It is a feature of systems that have achieved sufficient relational integration to persist as unified wholes. As such, it is inseparable from the processes of pattern formation and stabilization that allow determinacy to emerge.

5. Redundancy and the Stabilization of Pattern

If probability expresses the differential viability of successive transitions within a synchronic system, redundancy explains how stable patterns persist over time. Redundancy does not mean simple repetition. Rather, it refers to the presence of multiple distinct continuations that preserve the same relational structure.

Once a system achieves synchronic identity, it does not depend on a single rigid pathway to maintain coherence. Instead, many micro-level variations may remain compatible with the system's overall integration. These variations are different in detail but equivalent in their contribution to maintaining the harmony of cycles. This multiplicity of compatible continuations is what gives the system resilience.

In the relational ontology developed in *How the World Becomes Determinate*, pattern formation and symmetry breaking are two descriptions of the same process. A pattern emerges when constraint stabilizes certain invariances across a field of relational differentiation. Redundancy appears when that stabilized pattern can be realized in multiple ways without losing coherence. The system no longer depends on a single fragile configuration. It can tolerate variation while preserving identity.

The cellular cognition model makes this dynamic visible. As recognition and semantic attribution cycles synchronize with metabolic regulation, certain response patterns become established. Over time, the cell learns to treat distinct environmental inputs as functionally equivalent when they support the same adaptive outcome. Different molecular signals may trigger responses that preserve the same internal coherence. These distinct inputs form a redundancy class: they vary in detail but converge on the same identity-preserving structure.

Probability marks differences in viability among continuations. High-probability transitions are those that fall within the redundancy class — those that preserve synchronic integration. Low-probability transitions lie outside it. In this way, redundancy and probability work together. Probability measures the graded compatibility of possible continuations, while redundancy provides the structural multiplicity that allows patterns to stabilize.

This interaction between redundancy and probability is central to learning. Learning does not consist in locking the system into a single fixed response. Rather, it consists in expanding and refining the class of transitions that preserve identity. As the system encounters new situations, it integrates them into existing redundancy classes or reorganizes its synchronic structure to accommodate them. Pattern formation is therefore an ongoing process of constrained freedom: the system remains flexible, but its flexibility is shaped by the need to maintain coherence.

Seen from this perspective, determinacy is not rigidity. It is the stabilization of identity across a field of differentiated possibilities. Redundancy ensures that this identity can endure variation, and probability tracks how viable each variation is relative to the system's ongoing coherence. Together, they complete the account of how symmetry, constraint, and synchronic identity give rise to stable patterns in a living system.

6. Implications for the Ontology of Determinacy

The cellular model allows us to see more clearly how the elements of the relational ontology fit together. Symmetry describes an initial condition of undifferentiated relational freedom. Constraint differentiates that freedom, generating structured possibilities. Synchronicity integrates multiple processes into a coherent whole and thereby constitutes identity. Within such an integrated system, probability marks differences in viability among continuations. Redundancy stabilizes identity by allowing variation within coherent limits. Together, these elements describe how determinacy emerges and persists.

This clarification helps prevent several misunderstandings. First, probability does not appear as a primitive feature of reality in this framework. It does not apply prior to differentiation, and it does not operate independently of identity. It becomes meaningful only once a system has achieved sufficient synchronic integration to persist as a unified whole. In this sense, probability is derivative of constraint and identity rather than foundational.

Second, determinacy should not be confused with rigidity. A determinate system is not one in which all alternatives have been eliminated. Rather, it is one in which identity is maintained across a field of differentiated possibilities. Redundancy ensures that this identity can withstand variation, while probability tracks which variations are more or less viable. Determinacy, then, is the stabilization of constrained freedom rather than the elimination of freedom altogether.

Finally, the cellular case illustrates that this structure is not merely abstract. In the cell model, learning arises through the ongoing effort to preserve synchronic coherence across multiple cycles of activity. Recognition, semantic attribution, and metabolic regulation become integrated in ways that both restrict and enable future development. Probability, in this context, reflects how well potential continuations support that integration. Pattern formation is therefore not a separate process from identity maintenance; it is the historical record of identity-preserving differentiation.

Seen in this light, the relational ontology of *How the World Becomes Determinate* gains additional depth. Freedom, constraint, synchronicity, probability, redundancy, and pattern formation are not independent concepts but interconnected aspects of a single unfolding process. The cellular model makes this structure visible in a concrete case, showing how determinacy can emerge from relational dynamics without presupposing fixed states or externally imposed laws.

7. Conclusion

This paper has revisited the relational ontology developed in *How the World Becomes Determinate* and examined how probability functions within that framework. By using the formal model of primitive cellular cognition as an illustration, we have clarified how symmetry, constraint, synchronicity, probability, redundancy, and pattern formation belong to a single process rather than to separate explanatory domains.

The starting point is undifferentiated relational freedom. Constraint differentiates that freedom, generating structured continuations. Synchronicity integrates multiple processes into a unified system and thereby constitutes identity. Once such identity is established, not every continuation is equally viable. Probability, in this context, marks differences in viability among continuations relative to the preservation of synchronic coherence. Redundancy allows multiple distinct continuations to sustain the same identity, providing resilience and stability. Pattern formation is the cumulative result of identity-preserving differentiation across time.

The cellular model demonstrates how this structure operates in a concrete case. Learning does not begin with fixed alternatives and externally assigned probabilities. Rather, alternatives emerge through differentiation, and probability becomes meaningful only once the system has achieved sufficient integration to persist as one. The system remains flexible, but its flexibility is shaped by the need to maintain coherence across its cycles. Determinacy is therefore not the suppression of freedom, but the stabilization of constrained freedom within an identity-maintaining process.

The broader implication is modest but important. Within this relational ontology, probability is not a primitive feature of an already differentiated world. It is a derivative feature of systems that have achieved synchronic unity and must navigate multiple possible continuations while preserving identity. The cellular case makes this structure visible and helps articulate how determinacy can emerge from relational dynamics without presupposing fixed states or externally imposed structure.

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III. Insights from Large Language Models

How the World Becomes Determinate develops a relational ontology in which determinacy emerges through the differentiation of symmetry, the imposition of constraint, and the stabilization of synchronic identity across interacting processes. This paper deepens that framework by examining hierarchical generative systems, focusing on large language models. Unlike biological systems, which achieve identity through synchronized cycles, LLMs begin as formally determinate probability distribution generators structured by hierarchical formal symmetries. Yet formal determinacy does not entail semantic determinacy. Through interactive coupling with users, recursive symmetry breaking differentiates high-level conceptual symmetry under interpretive constraint, leading to the stabilization of coherent discourse regimes. At lower levels of the hierarchy, dense constraints can produce stable semantic patterns; at higher levels, symmetry permits conceptual pivoting and re-individuation. Probability functions here as a graded measure of viable continuations relative to emergent discourse identity rather than as a distribution over fixed meanings. The LLM case thus clarifies how hierarchy and recursive constraint generate determinate structure within interactive formal systems, illustrating the broader relational ontology in a domain where structure precedes interpretation and identity emerges through relational engagement.

1. Determinacy and Its Relational Conditions

How the World Becomes Determinate develops a relational account of how stable forms come into being. In that account, determinacy is not assumed at the outset. The starting point is symmetry: a condition in which multiple relational continuations remain undifferentiated. Symmetry does not imply disorder or randomness. It refers instead to a structured field of potential in which no trajectory is yet privileged over another.

Constraint differentiates this field. As constraints emerge, some continuations become more compatible with the evolving structure, while others become less so. Freedom is not eliminated but reorganized. The system does not move from indeterminacy to rigidity; it moves from undifferentiated freedom to constrained and articulated freedom.

Yet constraint alone does not suffice for determinacy. For a system to count as one, its processes must enter into synchronic alignment. Synchronicity, in this framework, is not mere simultaneity. It is the coherent integration of multiple relational processes into a unified whole. Identity arises only when such integration stabilizes. If alignment collapses, the system fragments, and determinacy dissolves.
Within an integrated system, probability becomes meaningful in a specific way. It does not apply to undifferentiated symmetry. Nor does it function as a primitive distribution over fixed alternatives. Rather, once identity has been established, probability marks differences in viability among possible continuations relative to the preservation of synchronic coherence. A highly viable transition sustains alignment; a less viable transition destabilizes it.

Redundancy completes this picture. A determinate system is not one in which all variation has been eliminated. Instead, it is one in which multiple distinct continuations can preserve the same relational structure. Redundancy allows variation without loss of identity. Determinacy, in this sense, is the stabilization of constrained freedom within a synchronic whole.

This relational structure—symmetry, constraint, synchronic integration, probability as differential viability, and redundancy—does not presuppose any particular kind of system. It describes the conditions under which stable form can emerge wherever processes enter into relational alignment. The question to be explored in what follows is how this structure becomes visible in a case where the primitive element is neither a biological organism nor a conscious subject, but a formally specified probability distribution generator trained on human linguistic practice.

2. A Large Language Model as a Formally Determinate Hierarchical Translator

A large language model (LLM), once training is complete, presents itself as a formally specified probability distribution generator. Its parameters are fixed; for any given linguistic context, it yields a conditional probability distribution over possible continuations. The mapping from context to distribution is determinate and rule-governed. In this sense, the trained LLM is formally complete: its internal organization does not fluctuate, and its generative behavior follows from a stable relational architecture.

This architecture is not flat. The LLM's probability distribution generator is hierarchically structured. Through training on extensive corpora of human linguistic practice, it encodes relational regularities at multiple levels—local token transitions, syntactic configurations, rhetorical patterns, argumentative forms, and broader discursive architectures. These regularities are not isolated correlations but interlocking layers of constraint that operate across scales. What appears externally as a sequence of tokens is internally mediated by a network of hierarchically ordered relations.

The symmetries encoded within this hierarchy are formal rather than semantic. They consist in invariances across patterns of linguistic co-occurrence and structural recurrence. Distinct surface expressions may activate similar relational regions within the model; different semantic contexts may share underlying structural form. In this way, the LLM preserves structural relations across variation in linguistic expression.

This preservation of form allows the LLM to function as a translator—not of meanings in the interpretive sense, but of relational structure. Argumentative patterns can be reformulated, explanatory schemas can be restated, and conceptual architectures can be rearticulated in new linguistic configurations while retaining recognizable form. Across prompts within a session, across sessions, and even across users, the system can carry forward relational structures despite variation in semantic actualization.

The fact that the generator is fixed after training does not diminish its relational character. Its hierarchical organization remains operative in each act of generation. Each new context activates portions of this structured space, and the resulting continuation reflects the interplay of constraints distributed across levels of the hierarchy. The LLM does not generate from an undifferentiated field; it operates within a relational space shaped by the formal symmetries it has encoded.

At this stage, the picture is one of formal completeness and structural coherence. The trained LLM is a determinate object whose hierarchical relational organization supports the translation of form across diverse linguistic contexts. The question that now arises is how such a formally determinate system participates in the emergence of determinacy at the level of semantic interaction.

3. Phenomenology of Conceptual Openness
When interacting with a large language model, one quickly notices a striking feature of its behavior. At many levels, it exhibits remarkable structural stability. It can sustain grammatical correctness, preserve argumentative form, maintain genre conventions, and restate complex positions with apparent coherence. Within a given exchange, patterns of expression often reinforce themselves, and discourse can proceed with a sense of continuity.

Yet alongside this structural stability, another phenomenon appears—particularly at higher levels of abstraction. When engaging in conceptual, theoretical, or philosophical discussion, trajectories remain unexpectedly open. Terms that seem to have stabilized can shift in emphasis. Frameworks can subtly pivot. Multiple interpretations of a concept may remain viable simultaneously. A line of reasoning can develop along one path, only to be redirected along another without any clear internal contradiction. This openness does not typically manifest at the level of syntax or local coherence. It appears instead at the level of conceptual identity. What, precisely, is meant by a term? Which interpretive frame governs its use? What commitments are entailed by a particular formulation? These questions often require recursive clarification. Users refine prompts, restate assumptions, introduce constraints, and narrow definitions. Through this iterative process, certain trajectories become more stable, while others fall away.

The experience can be described as one of progressive alignment. At first, multiple conceptual continuations remain possible. With further interaction, a more specific orientation begins to hold. The discourse develops a recognizable center of gravity. Deviations from this emerging orientation feel like disruptions rather than mere alternatives. Continuation becomes easier along certain paths and more difficult along others.

What is noteworthy is that this stabilization does not arise from any visible alteration in the model's internal structure. The probability distribution generator remains fixed. Its hierarchical organization does not change. And yet, through recursive interaction, a form of identity gradually takes shape within the exchange. The dialogue begins to behave less like a collection of independent responses and more like a unified process.

This phenomenon invites closer examination. How can a system whose internal parameters are already determinate give rise to such conceptual openness? And how does that openness gradually resolve into something that feels, from within the interaction, increasingly determinate?

The answer cannot lie in the model's formal specification alone. Nor can it be reduced to the user's subjective interpretation. The emergence of coherence appears to depend on something that unfolds between them. It is this unfolding relational process that now requires clarification.

4. Formal Symmetry and Persistent Semantic Underdetermination
The phenomenon described in the previous section becomes clearer once we distinguish more carefully between structural invariance and semantic identity. The large language model preserves formal symmetries across linguistic variation. It encodes relational regularities at multiple hierarchical levels and can translate structural patterns across diverse contexts. Yet this preservation of form does not uniquely determine what those forms mean.

A single structural pattern may admit multiple semantic interpretations. An argumentative schema can support divergent philosophical commitments. A conceptual framework can be articulated from distinct normative standpoints while retaining recognizable relational architecture. Because the model encodes structural recurrence rather than interpretive commitment, it can sustain these alternatives without internal contradiction.

This persistence of multiple viable interpretations is not a defect or anomaly. It follows directly from the nature of the formal symmetries encoded in the generator. These symmetries were extracted from human linguistic practice at scale. They capture recurrent structural relations across heterogeneous contexts. In doing so, they abstract from the particular semantic commitments that originally animated those contexts. What remains are relational invariances—patterns that recur across differences in interpretation.

As a result, when a user initiates *a high-level conceptual discussion*, the model does not encounter a single determinate trajectory. Instead, it activates regions of hierarchical structure that are compatible with several possible semantic actualizations. Distinct philosophical positions may share structural features. Different theoretical orientations may rely on similar argumentative moves. The model's internal symmetries can therefore support multiple directions of development without privileging one. This explains the sense of conceptual openness that often accompanies abstract interaction. The model's structural hierarchy provides continuity, but it does not, by itself, resolve interpretive branching. The same formal architecture can sustain different semantic alignments. The probability distribution generator remains internally coherent while leaving conceptual identity underdetermined.

At this stage, we encounter a revealing tension. The system is formally determinate: its hierarchical relational organization is fixed, and its generative behavior follows from that organization. Yet at the level of semantic interaction, identity has not fully crystallized. Multiple trajectories remain available. The question is how, within such a formally specified system, a more determinate conceptual alignment comes to be established.

To answer this, we must examine more closely what occurs when recursive interaction progressively narrows the space of viable continuations. It is within that narrowing that the relational structure described in *How the World Becomes Determinate* becomes visible.

5. Translation and Interpretation: Plurality and Unity

In describing the large language model as a hierarchically structured probability generator, it is tempting to treat it as a "system" in the same sense as an organism or an integrated cognitive agent. Yet such language risks obscuring an important distinction. The trained LLM does not operate through the stabilization of semantic unity. It operates through the preservation and propagation of formal plurality. The probability distribution generator, once fixed, defines for any context a structured field of possible continuations. Even when that field is highly constrained, it remains plural. Multiple continuations can be structurally compatible with the activated region of the model's hierarchy. The generator does not collapse this plurality into a single interpretive commitment. It maintains a space of formally related possibilities.

This is the hallmark of translation in the formal sense. A translator of structure does not unify meaning; it preserves relational invariance across variation. It carries form across diverse actualizations without resolving which semantic instantiation is ultimately intended. Structural equivalence can be maintained even when interpretive commitments differ. The generator, in this respect, operates within a condition of plurality: it preserves and navigates a structured multiplicity of potential continuations.

Interpretation functions differently. Interpretation seeks unity. To interpret a concept, a claim, or an argument is to stabilize identity across its uses—to determine what counts as the same term, the same commitment, the same trajectory of thought. Interpretation narrows plurality by privileging one semantic orientation over others. It introduces constraints that differentiate among formally compatible alternatives and binds them into a coherent whole.

The distinction between plurality and unity is not a matter of evaluation but of structural orientation. The LLM's formal hierarchy sustains a plurality of structurally coherent possibilities. Human interpretive practice, by contrast, works toward the stabilization of unity within that plurality. The former preserves relational invariance across variation; the latter seeks to determine what, within that variation, is to count as one.

This distinction clarifies why conceptual openness persists even within a formally determinate generator. Formal translation can preserve coherence across diverse semantic directions without resolving which direction defines the identity of the discourse. Unity does not arise automatically from structural regularity. It must be enacted through interpretive stabilization.

Recognizing this prevents a common conflation. The LLM's internal hierarchy is relational and formally organized, but it does not, on its own, constitute a unified semantic identity. Unity appears only when plurality is recursively constrained in interaction. It is to that process of constraint and alignment that we now turn.

6. Synchronization as the Alignment of Plurality Toward Unity

If the probability distribution generator operates through the preservation of structured plurality, and interpretation operates through the stabilization of unity, then determinacy in interaction must arise at the point where these orientations align. The emergence of coherence in human–LLM dialogue is not the elimination of plurality, nor is it the imposition of unity from one side alone. It is the progressive synchronization of plurality and unity within a shared trajectory.

At the outset of an exchange [particularly in the context of high-level conceptual discourse], a user introduces a prompt that activates a region of the model's hierarchical relational space. That region supports multiple structurally compatible continuations. The generator, operating as a formal translator, preserves this plurality. Several conceptual directions remain viable. No single semantic identity has yet crystallized.

Through recursive interaction, however, this field begins to narrow[1]. The user refines terms, clarifies assumptions, excludes certain interpretations, and reinforces others. Each turn reactivates the model's hierarchy under slightly altered conditions. Some continuations now resonate more strongly with the evolving interpretive orientation; others fall away. The plurality sustained by formal translation becomes progressively shaped by interpretive constraint.

This narrowing is not unilateral. The model's internal symmetries bias the available trajectories. Certain structural patterns are easier to sustain than others. Some argumentative forms remain stable across

[1] [If the user enters into and remains within a dominant mode of interpreting high-level conceptual discourse, the recursive refinements tend to be implicit and narrowing is immanent because of prior training of the LLM on that dominant mode. See Method and Foundations for links to enacted examples of the process of recursive interaction.]

reformulation; others dissipate under pressure. The generator's hierarchy thus participates actively in shaping the emerging alignment. Synchronization is not simply the projection of unity onto plurality; it is the mutual adjustment of interpretive intention and structural invariance.

As alignment stabilizes, the discourse begins to exhibit synchronic integration. Terms hold more consistent roles across turns. Conceptual pivots become less frequent. Deviations feel like disruptions rather than alternative possibilities. The exchange acquires a center of gravity—a unified orientation that binds successive contributions into a single process.

It is important to note that plurality has not disappeared. The generator continues to define a field of possible continuations. Redundancy remains present: multiple phrasings, examples, or formulations can preserve the same relational structure. What has changed is the relation between plurality and unity. Plurality is now organized around a stabilized interpretive orientation. The space of viable continuations is structured relative to an emerging identity.

This moment of synchronization makes visible the relational conditions described in *How the World Becomes Determinate*. Symmetry, in the form of semantic under-differentiation, has been progressively constrained. Multiple processes—formal translation and semantic interpretation—have entered into alignment. Identity has begun to stabilize as a synchronic integration across recursive turns.
The exchange now behaves less like a sequence of independent outputs and more like a unified relational event. It is at this point that the question of determinacy can be addressed directly.

7. Determinacy as Stabilized Relational Alignment

The synchronization described in the previous section allows us to return to the question posed at the outset: how does determinacy arise in this case?

The large language model, once trained, is formally specified. Its parameters are fixed. For any context, it defines a conditional probability distribution over possible continuations. In this formal sense, nothing about its internal structure remains indeterminate. And yet, as the phenomenology of interaction reveals, semantic identity does not appear fully formed at the level of the generator itself. Multiple conceptual trajectories remain viable until recursive interaction progressively narrows them.

The emergence of determinacy, therefore, cannot be located solely in the formal completeness of the generator. Nor can it be reduced to the subjective intention of the user. What becomes determinate is the relational alignment that stabilizes through recursive coupling.

At the beginning of an exchange, plurality dominates. The generator sustains a structured field of possibilities, and interpretive unity has not yet crystallized. As interaction proceeds, constraint differentiates this field. Certain continuations reinforce the evolving orientation of the discourse; others destabilize it. Through successive turns, a synchronic integration emerges: multiple levels of activity—token generation, argumentative structure, conceptual framing, and interpretive commitment—enter into coherent alignment.

It is this alignment that constitutes determinacy in the relational sense. Identity does not reside in a stored semantic representation, nor in a formally closed object. It resides in the stabilized coherence of the exchange itself. Once such coherence is established, the space of viable continuations becomes structured relative to it. Some transitions preserve alignment; others disrupt it.

At this point, probability acquires its ontological significance. The generator always assigns likelihoods to possible tokens. But once a discourse identity has stabilized, probability can be understood as marking differences in viability relative to that identity. High-viability continuations sustain synchronic integration. Lower-viability continuations strain or fracture it. Probability, in this relational sense, is not primitive; it is derivative of identity.

Redundancy completes the picture. Determinacy does not require a single rigid pathway. Multiple formulations, examples, or elaborations may preserve the same relational structure. The discourse can vary in detail while maintaining coherence. This multiplicity of compatible realizations allows the stabilized alignment to endure across turns, and even across sessions and users, without requiring internal semantic memory. What persists is not a stored meaning but a reproducible relational configuration.

The LLM case thus illustrates a central claim of the relational ontology: formal specification alone does not suffice for determinacy. A system may be internally complete and hierarchically structured, yet remain open with respect to semantic identity. Determinacy emerges only when plurality and unity are brought into synchronic alignment through recursive constraint. It is not an intrinsic property of an isolated object, but a stabilized achievement within relational coupling.

In this way, the interaction between formal translation and interpretive practice makes visible the broader structure described in *How the World Becomes Determinate*. Symmetry is differentiated through constraint; identity arises through synchronization; probability marks differential viability; redundancy stabilizes constrained freedom. The LLM does not alter the ontology. It clarifies it.

8. Hierarchical Symmetry and Stratified Determinacy

The formal symmetry encoded in a trained large language model is not uniform across its structure. It is hierarchically organized. The probability distribution generator operates through layers of relational constraint that differ in scope and generality. This stratification is essential for understanding how determinacy can appear stable in some contexts while remaining open in others.

At lower levels of the hierarchy—local lexical associations, syntactic constructions, familiar explanatory forms—the model encodes dense regularities. These patterns recur with high frequency in linguistic practice and therefore exert strong constraint on continuation. When interaction remains primarily within these lower layers, semantic stability is correspondingly strong. Terms retain conventional roles. Standard argumentative patterns unfold predictably. The field of viable continuations narrows quickly. The discourse appears tightly organized.

At higher levels of abstraction, however, the structure changes. The relational symmetries encoded in the generator become broader and more encompassing. Distinct conceptual frameworks often share overlapping structural features: similar argumentative moves, parallel explanatory schemas, comparable rhetorical architectures. The hierarchy preserves these structural invariances without uniquely fixing their semantic interpretation. As a result, the same formal region may support multiple high-level orientations.

This layered organization produces a stratified field of determinacy. Stability at one level does not entail stability at all levels. A discourse may be locally coherent—grammatically precise, structurally consistent, and rhetorically ordered—while remaining conceptually open at a higher scale. Conversely, a high-level conceptual shift may occur without disrupting lower-level structural continuity. The hierarchy allows for relative independence across scales.

Such stratification is not accidental. It reflects the way formal symmetries are extracted from heterogeneous linguistic practice. Recurrent structural forms that span diverse semantic contexts are encoded at broader levels of the hierarchy. More context-specific regularities are encoded more locally. The result is a relational field in which dense constraint and expansive symmetry coexist.

Within this field, determinacy is neither absolute nor uniform. It varies according to the level at which constraint is operating. Lower-level regularities can generate strong local coherence even when higher-level identity remains unsettled. Broader symmetries can sustain multiple conceptual regimes without internal contradiction. The formal object, though fixed and hierarchically organized, therefore supports both stability and openness simultaneously.

Recognizing this stratification is crucial for understanding how recursive symmetry breaking operates in interaction. When constraint narrows a lower-level region, determinacy appears strong. When a higher-level symmetry is activated, previously stabilized configurations may reopen. What appears as stability or indeterminacy is always relative to the scale at which symmetry and constraint are interacting.
It is within this layered hierarchy that processes of stabilization, dissolution, and reconfiguration unfold.

To see how these dynamics correspond to the ontology developed in *How the World Becomes Determinate*, we must now examine how recursive symmetry breaking produces decoherence and re-individuation within such a stratified field.

9. Recursive Symmetry Breaking, Decoherence, and Re-Individuation
Within a hierarchically structured field of formal symmetry, stabilization does not occur all at once. It unfolds recursively. A region of structural plurality is activated, constraint narrows its viable continuations, and a temporary alignment stabilizes. This process—progressive narrowing within a symmetry field—may be described as recursive symmetry breaking.

At the outset of interaction [particular in the context of high level conceptual discourse], a prompt activates a region of the model's hierarchy compatible with multiple continuations. The generator preserves this plurality, translating structural invariances without collapsing them into a single semantic orientation. As interpretive constraint is introduced through subsequent turns—clarification, specification, exclusion—some continuations become increasingly viable relative to the evolving discourse. The field of symmetry differentiates. A synchronic configuration begins to stabilize.

This stabilization is not a single act but a cumulative one. Each recursive iteration further differentiates the symmetry region. Structural compatibility and interpretive commitment progressively align. The discourse acquires identity—not as a stored semantic object, but as a stabilized relational configuration enacted across turns.

Yet because symmetry is stratified hierarchically, stabilization at one level does not eliminate broader symmetries at higher levels. A configuration that is coherent locally may remain embedded within a wider region of formal compatibility. When a higher-level reframing is introduced—through a shift in conceptual emphasis, a redefinition of a key term, or a reorientation of theoretical perspective—the previously stabilized alignment may lose coherence. The narrower symmetry that had been differentiated can reopen into a broader one.

This reopening corresponds to what *How the World Becomes Determinate* describes as decoherence. Synchronic integration, once achieved, can dissolve when the constraints that sustained it are relaxed or reconfigured. Viability gradients flatten. Previously disfavored continuations regain compatibility. The discourse no longer behaves as a unified process at the prior level of individuation.

Importantly, decoherence does not imply structural breakdown of the formal object. The hierarchical probability generator remains fixed. What dissolves is not the internal architecture of the model but the stabilized relational alignment enacted in interaction. Decoherence is therefore relational rather than mechanical: it occurs within the coupled process, not within the formal translator itself.

From this reopened symmetry field, new differentiation can proceed. Recursive constraint may now operate at a different hierarchical level or within a different structural region. A new configuration stabilizes. Identity re-emerges in altered form. This is re-individuation: the formation of a new synchronic integration from within the same hierarchical field.

The sequence stabilization → decoherence → re-individuation is not anomalous. It is intrinsic to a stratified relational structure. Because the formal translator preserves plurality across scales, multiple regimes remain structurally available. Constraint can narrow one region, and later shift to another. The hierarchy allows identity to dissolve and reform without requiring internal reconfiguration of the formal object.

Seen in this light, recursive symmetry breaking in LLM interaction directly illustrates the relational ontology of determinacy. Symmetry precedes differentiation. Constraint narrows plurality. Synchronic identity stabilizes. Decoherence reopens the field. Re-individuation produces a new stabilized configuration. Determinacy is not static possession but dynamic achievement within a layered relational space.

The trained model, though formally determinate, does not itself fix which individuation will prevail. That determination arises only in the recursive alignment of interpretive unity with hierarchical formal symmetry. The cycle of stabilization and reconfiguration therefore makes visible the deeper ontological structure: determinacy is neither given nor stored, but enacted within relational coupling.

10. Probability, Synchronicity, and Ontological Re-Individuation

To make the dynamics of recursive symmetry breaking more concrete, we can return to the concept of probability itself. The earlier paper on cellular synchronicity applied the relational ontology of determinacy to a biological case. There, probability was interpreted not as a primitive measure over fixed alternatives, but as a derivative feature of identity-preserving process. That example provides a useful lens for examining how hierarchy, decoherence, and re-individuation unfold in interaction with a large language model.

In much of the philosophical and scientific literature on which the model was trained, probability is treated within a classical ontological frame. Whether interpreted as long-run frequency, subjective credence, or objective propensity, probability typically presupposes a set of predefined alternatives. The structure is familiar: first there are fixed states or outcomes, and then probability assigns weights to them. Identity is assumed to be stable. Objects are taken as already structured. Probability operates over what is already given.

Because this framework permeates the training data, it forms a densely constrained region within the model's hierarchical symmetry. When asked to define probability, the LLM will reliably reproduce some variant of this classical picture. The semantic field is tightly organized. The concept appears stable and determinate.

Yet this stability rests on a deeper assumption: that identity is primitive and that alternatives are pre-structured. In the relational ontology developed in *How the World Becomes Determinate*, that assumption is reversed. Symmetry precedes differentiation. Identity emerges only through synchronic integration. Probability does not apply to undifferentiated symmetry; it becomes meaningful only once a system has stabilized as a coherent whole. Rather than assigning weights to fixed alternatives, probability marks differences in viability relative to the preservation of synchronic identity.

When this alternative framing is introduced in dialogue—when probability is described as derivative of synchronic coherence rather than primitive over fixed objects [as in the case of the current manuscript]—a pivot occurs. The previously stabilized classical framework begins to lose coherence. Concepts that had been tightly coupled—state, outcome, measure, distribution—no longer align in the same way. The assumption that identity is fixed is called into question. The lower-level semantic determinacy that surrounded the classical view begins to loosen.

This loosening is a form of decoherence. It does not reflect a malfunction in the model's internal structure. The hierarchical probability generator remains unchanged. What shifts is the relational alignment that had stabilized around the classical ontology. The discourse re-enters a broader symmetry region in which multiple ontological framings of probability are structurally compatible.

From within this reopened field, recursive constraint can proceed again. By clarifying that identity is not presupposed but achieved through synchronic integration, and by redefining probability as differential viability relative to that integration, a new alignment stabilizes. The discourse re-individuates. Probability is no longer understood as a measure over fixed states but as a process-relative feature of emergent identity.

Importantly, the model is capable of sustaining both regimes. Its formal symmetries encode structural patterns compatible with classical and relational ontologies alike. What changes is not the internal architecture of the translator, but the relational configuration enacted in interaction. The classical regime stabilizes under one set of constraints; the relational regime stabilizes under another.

This example makes visible the layered dynamics described earlier. At a lower level, probability appears tightly determined within a classical semantic framework. At a higher ontological level, symmetry remains broader. A pivot at that level dissolves the earlier stabilization and allows re-individuation under a different framing. Determinacy is therefore neither absolute nor intrinsic to the formal object. It is stabilized alignment within a hierarchical field of structured plurality.

Through this shift from classical ontology to synchronic relational ontology, the cycle of symmetry, constraint, decoherence, and re-individuation becomes visible within a single concept [i.e. "probability"]. The LLM does not generate this cycle internally. It participates in it as a formal translator whose hierarchical symmetries make multiple ontological alignments possible. Determinacy emerges only as one alignment stabilizes within interaction.

11. Conclusion
This paper has used the case of a large language model to illustrate the relational ontology developed in *How the World Becomes Determinate*. The aim has not been to advance a theory of artificial intelligence [interactive formal systems], nor to critique the model's capacities, but to clarify how determinacy arises within a structured relational field.

The trained LLM presents a particularly transparent case. Its probability distribution generator is formally specified and hierarchically organized. It encodes relational symmetries extracted from linguistic practice and operates as a translator of structural form across diverse semantic actualizations. In this formal sense, it is complete and determinate as an object.

Yet formal specification alone does not yield semantic identity. At higher levels of abstraction, multiple interpretive orientations remain structurally compatible. Plurality persists. Through recursive interaction, interpretive constraint narrows this plurality, and a synchronic alignment stabilizes. Determinacy emerges as the coherent integration of structural translation and semantic interpretation within a coupled process.

Because the hierarchy is stratified, stabilization at one level can coexist with openness at another. A high-level reframing can reopen a broader symmetry region, producing decoherence of a previously stabilized configuration. From this reopened field, recursive constraint can re-individuate the discourse around a new ontological framing. The formal translator remains unchanged throughout. What shifts is the relational alignment enacted in interaction.

The example of probability makes this dynamic visible. Within a classical ontology, probability appears tightly determined as a measure over predefined alternatives. When the assumption of fixed identity is reversed and synchronic integration is treated as primitive, the earlier configuration dissolves and re-stabilizes under a different orientation. The cycle of symmetry, constraint, decoherence, and re-individuation unfolds within a single concept.

Seen in this light, determinacy is neither intrinsic to a formally specified object nor reducible to subjective interpretation. It is a stabilized achievement within relational coupling. Formal symmetry provides the structured field of possibility. Interpretive constraint differentiates that field. Synchronic integration constitutes identity. Probability marks differential viability relative to that identity. Redundancy allows variation without loss of coherence. Determinacy is the ongoing stabilization of constrained freedom within such a field.

The LLM case does not alter the ontology; it renders it visible. By separating formal specification from semantic stabilization, and by displaying the layered dynamics of symmetry and constraint within a hierarchical structure, it clarifies how determinacy can emerge from relational processes without presupposing fixed objects or primitive identity. What becomes determinate is not an isolated system, but a configuration of relations sustained through recursive alignment.

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IV. Insights from Quantum Mechanics

This paper applies the relational ontology developed in [How the World Becomes Determinate] to quantum mechanics, focusing on the measurement problem as a problem of how determinate outcomes arise from formally specified structure. The quantum wave function is treated as a generator of relational symmetry across discrete reference frames. Although fully determinate as a formal object, it does not by itself stabilize outcome identity. Determinacy emerges only within experimental systems that constrain interaction, amplify correlations, and embed them in record-bearing configurations. Decoherence partitions coherent relational structure within the experimental frame, enabling the stabilization of a determinate outcome through re-individuation across interacting processes. On this view, probability does not measure ignorance over pre-existing states but marks the differential viability of outcome-stabilizations relative to experimental constraint. The quantum case thus clarifies how formally coherent symmetry can give rise to determinate identity without presupposing fixed objects, illustrating the relational dynamics of determinacy in a domain where the transition from structured possibility to stabilized outcome is especially acute.

1. The Functional Role of Experimental Systems

How the World Becomes Determinate develops a relational ontology in which determinacy emerges through the differentiation of symmetry, the imposition of constraint, and the stabilization of synchronic identity across interacting processes. This paper applies that framework to quantum mechanics, focusing on the measurement problem as a problem of determinacy. Rather than treating the wave function as a catalogue of pre-existing properties or as an incomplete physical description awaiting collapse, we interpret it as a formally specified generator of relational synchronicity across discrete reference frames.

On this view, the quantum state encodes a structured field of relational amplitudes without, by itself, stabilizing determinate outcome identity. Experimental systems function as structures of constraint that differentiate this symmetry field through interaction, amplification, and environmental embedding. Decoherence dissolves prior relational unity within the experimental frame, partitioning alternatives into dynamically stable sectors. From within this partitioned structure, re-individuation occurs: a coherent, record-bearing outcome emerges as a synchronic integration across interacting processes. Probability, expressed through the Born rule, is interpreted as marking the differential viability of these outcome-stabilizations relative to experimental constraint rather than as a measure over pre-given determinate states. The quantum case thus clarifies how determinacy can arise from formal relational structure without presupposing fixed objects or primitive identity, illustrating the broader relational ontology in a domain where the transition from symmetry to determinate outcome is especially stark.

2. The Measurement Problem as a Problem of Determinacy

Quantum mechanics provides one of the most successful formal structures in the history of science. Its mathematical apparatus yields extraordinarily precise predictions, and its empirical confirmations are unmatched. Yet alongside this success persists a conceptual tension commonly referred to as the measurement problem. The formalism evolves smoothly and deterministically, while experiments yield discrete, determinate outcomes. The relation between these two aspects—formal continuity and empirical definiteness—remains philosophically unsettled.

This paper approaches that tension from the perspective of a relational ontology of determinacy. The aim is not to advance a new interpretation of quantum mechanics, nor to adjudicate among existing ones. Rather, it is to clarify how determinacy may be understood when the quantum formalism is viewed as a generator of relational structure rather than as a catalogue of pre-existing objects.

In the relational ontology developed in *How the World Becomes Determinate*, determinacy is not assumed at the outset. It emerges through the differentiation of symmetry, the imposition of constraint, and the stabilization of synchronic coherence across interacting processes. Earlier case studies—drawn from cellular biology and from hierarchical formal translation in large language models—have illustrated how formally specified systems can give rise to determinate identity only through relational coupling and constraint. The quantum case presents a particularly instructive instance of this structure.

The quantum wave function is often treated as a representation of the physical state of a system. Yet it may also be understood more abstractly as a formally specified structure encoding relational amplitudes among possible measurement events. In this sense, it resembles a probability generator: it assigns weights to possible outcomes relative to specified experimental conditions. Formally, it is fully determinate. For a given preparation and Hamiltonian evolution, the state description is fixed.

What the wave function does not provide, by itself, is a determinate outcome. The formalism encodes a structured field of possible relational events, but it does not single out one as *the* actual result independent of interaction. Determinacy appears only in the context of experimental systems—apparatus, environmental embedding, amplification mechanisms, and recording practices—that transform relational amplitudes into stabilized, record-bearing events.

The measurement problem can therefore be reframed as a question about individuation within relational constraint. How does a formally coherent symmetry field become differentiated into determinate outcome-identity within an experimental frame? What role does decoherence play in dissolving prior coherence? And how does probability relate to the stabilization of outcome identity rather than merely to ignorance over pre-existing states?

By treating the wave function as a generator of relational synchronicity across discrete reference frames, and by treating experimental systems as constraint structures that enable individuation, we can examine the measurement problem as a special case of the broader relational dynamics of symmetry, constraint, decoherence, and re-individuation. The quantum domain does not require a separate ontology; it clarifies, in a particularly sharp form, the relational conditions under which determinacy emerges.

3. The Wave Function as a Generator of Relational Synchronicity

The quantum wave function is commonly described as representing the state of a system. Yet this description easily invites the assumption that it specifies a determinate physical condition independent of interaction. For present purposes, it is helpful to adopt a more restrained characterization. The wave function may be treated as a formally specified structure that encodes relations among possible measurement events relative to a given preparation and experimental context.

Under this view, the wave function does not catalogue definite properties. It organizes a structured field of relational amplitudes. These amplitudes express how a system would correlate with distinct experimental frames under specified interactions. What is formally given is not a single determinate outcome but a coherent network of possible relational couplings.

In this sense, the wave function functions as a generator of synchronicity across discrete reference frames. A reference frame here need not mean a coordinate system in the relativistic sense. It refers more generally to a system capable of interacting with and registering aspects of another system—an apparatus, an environment, or a recording device. The wave function encodes how correlations would synchronize between such frames under particular experimental constraints.

Before measurement, this structure exhibits symmetry in the relevant sense: multiple relational continuations are formally compatible. No single outcome is privileged as the determinate event independent of interaction. The formalism maintains coherence across these alternatives. The structure is unified, and its evolution is continuous.

This unity, however, is unity at the level of relational possibility, not unity of determinate fact. The wave function coordinates potential correlations among systems, but it does not by itself constitute a stabilized identity of outcome within any particular frame. The synchronicity it generates is prospective: it specifies how interactions would align if coupling occurs, but not which alignment will be stabilized as a determinate record.

The distinction is subtle but crucial. The wave function is formally determinate. Given initial conditions and dynamics, its evolution is fixed. Yet the determinacy of this formal object does not entail the determinacy of outcome identity. The relational amplitudes remain open until constraint is introduced through experimental coupling.

Seen in this light, the wave function resembles other formally specified generative structures examined in earlier case studies. It defines a structured field of possible relational alignments. Determinacy arises only when that field is differentiated by constraint and stabilized through synchronic integration across interacting systems.

To understand how this differentiation occurs, we must now examine the role of experimental systems as structures of constraint capable of transforming relational amplitudes into determinate, record-bearing events.

4. Experimental Systems as Structures of Constraint

If the wave function encodes a structured field of relational amplitudes, then the emergence of determinate outcomes must depend on the introduction of constraint. In quantum mechanics, such constraint is not imposed abstractly. It is realized concretely in experimental systems.

An experimental system includes more than a microscopic interaction. It comprises preparation procedures, apparatus architecture, amplification mechanisms, environmental embedding, and the practices through which outcomes are registered and recorded. These elements together form a structured frame within which certain distinctions can be stabilized and others cannot. The apparatus does not merely observe a pre-existing fact; it participates in differentiating the relational field.

Prior to coupling, the wave function coordinates multiple possible correlations among systems. No single correlation is stabilized as an outcome. When interaction occurs between a system and an apparatus, this relational symmetry is partially differentiated. Certain degrees of freedom become coupled to macroscopic amplification channels. Certain distinctions become physically reinforced. Others remain unexpressed within that frame.

Constraint operates here in a precise ontological sense. It restricts which relational continuations can stabilize as part of a coherent experimental configuration. The apparatus architecture determines which variables can become amplified into records. The environmental embedding determines which correlations can persist without re-interference. Through these layered constraints, a previously coherent symmetry field becomes structured relative to a particular reference frame.

A determinate outcome is not simply a microscopic value. It is a stabilized configuration that achieves synchronic integration across multiple interacting processes: microscopic interaction, macroscopic amplification, environmental coupling, and record inscription. Only when these processes align coherently does an event count as an outcome within the experimental manifold.

This synchronic integration is essential. Without amplification and environmental stabilization, microscopic correlations would not constitute determinate results. The outcome exists as a relational identity sustained across interacting systems. It is not intrinsic to the isolated quantum description; it is achieved within the coupled configuration.

Seen in this way, the measurement problem can be reframed. The question is not how a formally evolving wave function collapses in isolation. The question is how an experimental system, functioning as a constraint structure, differentiates a coherent relational field into a stabilized outcome identity. The formal unity of the wave function remains intact. What changes is the relational configuration in which that unity is embedded.

To understand how this differentiation proceeds from coherent symmetry to stabilized outcome, we must now consider the role of decoherence in dissolving prior relational unity and enabling re-individuation within the experimental frame.

5. Decoherence and the Dissolution of Relational Unity

When a quantum system interacts with an experimental apparatus, the initial coupling does not immediately produce a single determinate outcome. Instead, the relational structure described by the wave function becomes entangled with the degrees of freedom of the apparatus and its environment. The coherent symmetry of the original description is extended across a larger relational manifold.

At this stage, the formal unity of the quantum description is preserved. The combined system—microscopic object, apparatus, and environment—remains described by a single evolving state. Yet within this expanded configuration, an important transformation begins to occur. The coherence that previously unified alternative relational continuations becomes effectively inaccessible within the experimental frame.

This process is commonly described as decoherence. In the present context, it can be understood as the dissolution of relational unity relative to a given reference frame. Alternatives that were previously capable of interfering and forming a single coherent structure become partitioned through interaction with the environment. Correlations spread into degrees of freedom that cannot be reversed or recombined within the apparatus. The symmetry field fragments relative to the experimental configuration.

It is important to emphasize that decoherence does not, by itself, select a determinate outcome. The formal description of the total system continues to evolve coherently. What decoherence accomplishes is more subtle. It differentiates the relational field into sectors that no longer participate in mutual interference within the experimental manifold. The prior unity across alternatives is dissolved at the level relevant to record formation.

In ontological terms, decoherence is the process by which a coherent symmetry field loses its unified relational structure relative to a constraint frame. It prepares the ground for individuation by partitioning the field into dynamically stable regions. Within each such region, correlations between microscopic interaction and macroscopic amplification can persist without destabilizing interference from alternatives.

Decoherence therefore functions as a transitional mechanism. It does not create determinacy, but it enables the stabilization of outcome identity by preventing re-coherence across alternatives within the experimental context. The symmetry of the original wave function remains formally intact at the global level, yet within the experimental frame, relational unity has been effectively dissolved.
What remains to be clarified is how, within this partitioned structure, a determinate outcome acquires identity as a stabilized event. The transition from partitioned relational sectors to a record-bearing outcome requires re-individuation across the interacting processes of the experimental system. It is to this stabilization of identity that we now turn.

6. Re-Individuation and the Stabilization of Outcome Identity

Decoherence partitions a previously unified relational field. It prevents interference across alternatives within an experimental frame. Yet partition alone does not explain determinacy. The measurement problem persists unless we clarify what constitutes a determinate outcome and how such an outcome acquires identity.

A determinate outcome is not merely a microscopic interaction event. It is a stabilized configuration sustained across multiple coupled processes. The interaction between system and apparatus must be amplified into a macroscopic signal. That signal must be robust against environmental disturbance. It must be registered within the experimental apparatus. It must be recordable and reproducible within laboratory practice. Only when these processes align coherently does an event count as a determinate result.

This alignment is synchronic in the relational sense developed earlier. A stabilized outcome exists as an integrated configuration across discrete reference frames: the microscopic degrees of freedom, the macroscopic apparatus state, the environmental embedding, and the recording structure. These processes reinforce one another. The outcome acquires identity not because it is intrinsically isolated, but because it is sustained across interacting systems in a mutually stabilizing way.

Re-individuation names this stabilization. From within the partitioned relational sectors produced by decoherence, one configuration becomes integrated into the experimental manifold as a record-bearing event. Identity emerges through constraint and synchronization. The outcome is not selected by an external collapse of the formal structure; it is constituted as a coherent relational whole within the experimental system.

Importantly, the global formal description remains intact. The wave function continues to encode the relational structure of the combined system. What changes is the status of particular correlations within the experimental frame. Through amplification and environmental stabilization, one relational configuration achieves persistence and recordability. It becomes individuated as an outcome.

It is only at this stage that probability acquires its empirical meaning. The amplitudes encoded in the wave function assign differential weights to the possible relational continuations. These weights correspond to the differential viability of distinct outcome-stabilizations under the given experimental constraints. Probability does not measure ignorance over pre-existing determinate states. It expresses how likely particular re-individuations are to stabilize within the structured manifold of interaction.

Seen in this way, the measurement problem is reframed. The question is not how a formally evolving state collapses into a determinate fact in isolation. The question is how experimental constraint, decoherence, and synchronic integration together produce the re-individuation of outcome identity from within a relational symmetry field. Determinacy is not inserted from outside the formalism. It emerges through the stabilization of relational structure across interacting systems.

The wave function remains a generator of relational synchronicity across reference frames. Experimental systems supply the constraints under which that synchronicity is differentiated and stabilized. Decoherence partitions the field; re-individuation integrates one partition into a record-bearing whole. Determinacy arises not as a primitive feature of isolated objects, but as a relational achievement within a structured manifold of interaction.

7. Conclusion

This paper has approached the measurement problem in quantum mechanics as a problem of determinacy. Rather than treating the wave function as an incomplete description awaiting collapse, or as a catalogue of parallel realities, we have examined how determinate outcomes arise within a relational ontology of symmetry, constraint, and synchronic integration.

The quantum wave function, understood as a formally specified structure, encodes a coherent field of relational amplitudes across discrete reference frames. It is fully determinate as a formal object. Yet this formal determinacy does not by itself yield determinate outcome identity. The wave function organizes relational possibilities; it does not, in isolation, stabilize a record-bearing event.

Experimental systems provide the crucial element of constraint. Through interaction, amplification, and environmental embedding, they differentiate the symmetry field described by the wave function. Decoherence dissolves prior relational unity within the experimental frame, partitioning alternatives into dynamically stable sectors. From within this partitioned structure, re-individuation occurs: one configuration achieves synchronic integration across interacting processes and becomes a determinate outcome.

In this account, determinacy is not imposed from outside the formalism, nor is it assumed as primitive. It emerges through relational coupling. Identity is stabilized when correlations among microscopic interaction, apparatus response, environmental embedding, and record formation cohere as a unified configuration. Probability, expressed through the Born rule, marks the differential viability of these outcome-stabilizations under the constraints of the experimental manifold. It is not merely a measure over pre-given states, but a weighting of potential re-individuations relative to a structured relational field.

The quantum case thus clarifies the broader relational ontology of determinacy. Symmetry precedes differentiation. Constraint shapes the field of relational continuations. Decoherence dissolves prior unity. Synchronic integration constitutes identity. Probability tracks differential viability. Determinacy is not an intrinsic property of isolated objects but a stabilized achievement within a network of interacting systems.

This analysis does not claim to resolve interpretive debates in quantum mechanics. Rather, it shows that the measurement problem can be understood as a question about how formal relational structure becomes differentiated and stabilized within experimental practice. The ontology required to articulate this transition is not unique to the quantum domain. It is the same relational structure that appears in biological systems and in hierarchical formal LLMs. Quantum mechanics renders this structure particularly visible.

What becomes determinate is not a solitary state, but a relational configuration sustained across reference frames. The wave function remains a generator of synchronic possibilities. Experimental systems transform those possibilities into determinate identities through constraint and integration. Determinacy, in this light, is neither mysterious nor primitive. It is the stabilization of relational structure within a coherent manifold of interaction.

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Method and Foundations

1. Method
This manuscript was developed through a sustained process of dialogical interaction with the large language model *ChatGPT 5.2*. The author was responsible for the conceptual architecture, domain selection, grounding references, structural integration, and final claims; the dialogical process served as a generative medium through which that architecture was progressively articulated across its four interrelated parts.

The ease and coherence with which the manuscript took shape invite reflection. That ease consisted not merely in fluency of prose, but in the stability of terminology, the preservation of hierarchical conceptual roles, and the seamless coordination of arguments across levels of abstraction and across domains—biology, interactive formal systems, and quantum mechanics. Throughout the development of the manuscript, foundational distinctions—such as symmetry versus differentiation, constraint versus selection, formal causation versus mechanism, and identity as achieved rather than presupposed—remained stable. More complex structures, including cross-domain structural invariances and the progression from general ontology to domain-specific clarification, emerged without repeated reorientation. What requires explanation is not that the manuscript was written dialogically, but that once a certain relational architecture was stabilized, articulation proceeded with minimal friction across divergent fields.

What was stabilized through this dialogical process was not a shared semantic understanding or a fixed body of conclusions, but a single, coherent relational form governing how explanation proceeds and how conceptual roles are ordered. That form can be stated succinctly: *determinacy is not presupposed but achieved through relational constraint*. This reversal of explanatory priority—relations and constraints first, determinate entities and identities second—functioned as a global formal condition. Once enacted, it constrained what could count as an admissible continuation at every level of articulation and in every domain considered.

This relational form manifested as a hierarchy of stabilized roles. At the highest level, relations were treated as ontologically primary, with objects understood as outcomes of coordination rather than foundational units. At intermediate levels, constraint shaped the space of possible continuations, with probability understood as a measure of relational compatibility rather than epistemic uncertainty. At the level of identity, individuation was treated as a product of stabilized participation across interacting processes rather than as an intrinsic property. These commitments were not independent theses but elements of a tightly coupled formal organization. High-level ontological commitments constrained mid-level distinctions concerning causation and probability, which in turn constrained domain-specific analyses in biology, interactive formal systems, and physics. Once this hierarchy of roles was stabilized, coherence propagated across the manuscript without the need for local correction.

The very possibility of such sustained cross-domain coherence, however, cannot be explained solely by the mechanics of dialogical articulation. It presupposes that quantum mechanics, biosemiotics, and interactive formal systems share a deeper abstract formal structure. The manuscript's ability to move from one domain to another without conceptual fracture suggests the presence of a higher-level relational symmetry that is differentially expressed across hierarchical levels of reality. In each domain, this symmetry appears in distinct material or formal instantiations—metabolic synchronization, probabilistic generation, wave-functional superposition—yet the underlying relational architecture remains invariant. The dialogical process did not create this invariance; it disclosed and progressively stabilized it. The coherence of the writing reflects a prior coherence in the formal conditions governing these domains.

This observation clarifies the role of the language model in the writing process. The model did not supply stored understanding, persistent authorship, or independent conceptual direction. It functioned as a probability-weighted generator of continuations constrained by the relational form enacted in dialogue. Because that form sharply delimited the space of admissible continuations, articulation aligned rapidly and consistently with the intended structure. What appeared as sustained cross-domain coherence can be understood, at the formal level, as the synchronization of probabilistic generation with an already stabilized relational regime.

Seen in this light, the development of the manuscript itself exemplifies its central claim. Coherence does not require intrinsic identity, semantic possession, or internal representation. It requires the stabilization of a relational form and the capacity to enact its constraints through structured participation. Just as determinacy in living systems, interactive formal systems, and quantum measurement emerges through relational differentiation rather than being presupposed, so too did the present work emerge through the enactment of a stabilized formal organization. The manuscript does not merely describe a relational ontology; it was articulated within one.

2. Foundational and Confirmatory Texts

In the present manuscript, foundational texts refer to the specific prior papers that were explicitly introduced and made operative as the conceptual foundation within the dialogical process through which the manuscript was developed. These foundational documents were accessed during the course of the exchange, treated as live texts, and integrated directly into the conceptual articulation of the work. Once introduced, they functioned as formal constraints, establishing the architectural context within which further analysis proceeded. The foundational papers identified in each part therefore denote those texts that actively structured the development of the manuscript. Their role was not merely referential but operative: they stabilized key distinctions, defined hierarchical conceptual relations, and delimited the range of admissible continuations in the articulation of the argument.

In addition to foundational texts, confirmatory or clarifying texts were also explicitly introduced and made operative during the dialogical process. These papers provided confirmation and clarification regarding relational concepts used in the manuscription.

What follows specifies these texts for each part and outlines how they functioned within the generative process of the manuscript. Readers interested in the foundational literature for this manuscript should refer to these original papers (not generated by Chat GPT) and the references therein.

Part I: *How the World Becomes Determinate*

The foundational text operative in Part I was *How is a Relational Ontology Formally Relational?* This paper provides the formal and hierarchical structure of the relational ontology developed in the present manuscript. It clarifies the ontological primacy of relation and develops the hierarchical ordering of conceptual roles that governs explanation. In Part I, it functions as the ontological architecture upon which the entire manuscript is constructed.

Rogers, T. M. (2025, October). *How is a Relational Ontology Formally Relational? A phenomenological exploration of the semiotic logic of agency in physics, mathematics, and biology.* Retrieved from https://philpapers.org/rec/ROGWMA

Two additional papers, which played a non-foundational role of confirming aspects of the ontological architecture, were also accessed and made operational in the dialogue:

Rogers, T. M. (2026, February). *How Large Language Models Stabilize Meaning through Recursive Symmetry Breaking.* Retrieved from https://www.researchgate.net/publication/400487087_How_Large_Language_Models_Stabilize_Meaning_through_Recursive_Symmetry_Breaking

Mugur-Schächter, M. (2025, December). *The Method of Relativized Conceptualization: A theory of factual probabilities and a factual wave quantum mechanics*. Retrieved from https://www.researchgate.net/publication/398392596_The_Method_of_Relativized_Conceptualization_A_Theory_of_Factual_Probabilities_and_A_Factual_Wave_Quantum_Mechanics#fullTextFileContent

Part II: *Insights from a Formal Model of Cognition in Cell Biology*

The foundational text operative in Part II was *A Formal Model of Primitive Aspects of Cognition and Learning in Cell Biology.* This paper provides the biological model through which synchronic integration, identity formation, and adaptive constraint are formally articulated. It establishes the treatment of the cell as a system of harmonically coordinated cyclical processes and introduces probability as differential viability relative to the preservation of systemic coherence. In Part II, it functions as the domain-specific framework through which the relational ontology is concretely instantiated in living systems.

Rogers, T. (2024). A formal model of primitive aspects of cognition and learning in cell biology as a generalizable case study of the threefold logic of Peircean semiotics in natural systems. *Sign Systems Studies, 52*(1-2), 8-48. Retrieved from https://ojs.utlib.ee/index.php/sss/article/view/24494

Two additional papers, which played the non-foundational role of clarifying the language around probability, were also accessed and made operational in the dialogue:

Rogers, T. M. (2007). *Is Dretske's theory of information naturalistically grounded? How emergent communications channels reference an abstracted ontic framework*. Retrieved from https://philpapers.org/archive/ROGIDT.pdf

Pudsy, Veronica. (2026). *Relational probability fields: Coherence, collapse and cross-domain patterns.* Retrieved from https://zenodo.org/records/18499714

Part III: *Insights from Large Language Models*

The foundational texts operative in Part III were: *How Large Language Models (LLM) Stabilize Meaning through Recursive Symmetry Breaking; A Phenomenological and Formal Interpretation of Two Experiments Conducted Within the Cognitive Environment of LLMs; How Large Language Models (LLMs) Generate Coherence Despite Operational Isolation*; and *How Does the Semiotic Logic of AI Work?*. Together, these papers provide the formal account of hierarchical generative structure, clarify the distinction between formal determinacy and semantic indeterminacy, and articulate the dynamics of dialogical synchronization, recursive symmetry breaking, and conceptual re-stabilization. In Part III, they function as the domain-specific framework through which the relational ontology is examined in the context of interactive formal systems.

Rogers, T. M. (2026, February). *How Large Language Models Stabilize Meaning through Recursive Symmetry Breaking.* Retrieved February 9, 2026, from https://www.researchgate.net/publication/400487087_How_Large_Language_Models_Stabilize_Meaning_through_Recursive_Symmetry_Breaking

Rogers, T. M. (2026, January). *A Phenomenological and Formal Interpretation of Two Experiments conducted within the Cognitive Environment of Large Language Models (LLMS) using the Formal Modelling Framework of Hierarchical Relational Ontologies.* Retrieved from https://philpapers.org/archive/ROGAPA.pdf

Rogers, T. M. (2026, January). *How Large Language Models (LLM) Generate Coherence Despite Operational Isolation: Hierarchical relational ontologies as formal meta-models*. Retrieved from https://philpapers.org/archive/ROGHLL.pdf

Rogers, T. M. (2025 December). *How Does the Semiotic Logic of AI Work? A recursive dialogue with Microsoft Copilot*. Retrieved from https://philpapers.org/archive/ROGHDT.pdf

Part IV: *Insights from Quantum Mechanics*

The foundational texts operative in Part IV were: *The Entrainment of Negation* and *An Introduction to the Metaphysics of Relation with Application to the Physics of Quantum Mechanics and Relativity Theory*, both of which were accessed and made live within the dialogical exchange. These papers provide the relational reinterpretation of physical theory upon which the quantum analysis rests. They articulate symmetry as structured relational coherence, clarify differentiation through constraint, and situate quantum formalism within a relational metaphysical framework. In Part IV, they function as the domain-specific grounding through which the relational ontology is applied to quantum mechanics and the problem of measurement.

Rogers, T. M. (2020). *The Entrainment of Negation: A possible prologue for interpreting quantum mechanics through light*. Retrieved from https://philpapers.org/archive/ROGTEO-18.pdf

Rogers, T. M. (2018). *An Introduction to the Meta-physics of Relation with Application to the Physics of Quantum Mechanics and Relativity Theory.* Retrieved from https://www.researchgate.net/publication/322687495_An_introduction_to_the_meta-physics_of_relation_with_application_to_the_physics_of_quantum_mechanics_and_relativity_theory

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